GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Accounting for Secondary $PM_{2.5}$ Formation in Georgia

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INTRODUCTION

- Facilities applying for PSD air permits are required to model the impact of direct $PM_{2.5}$ emissions ($\geq$ 10 TPY) using AERMOD.
  - In addition, these facilities must account for the impact of secondary $PM_{2.5}$ formation from precursor emissions (NOx and/or $SO_2 \geq$ 40 TPY).
- AERMOD does not contain chemistry or aerosol formation modules
  - The secondary formation of $PM_{2.5}$ cannot be modeled directly in AERMOD.

“EQUIVALENT” DIRECT $PM_{2.5}$ EMISSIONS

- $PM_{2.5}$ offset trading ratios can be used to account for secondary formation of $PM_{2.5}$ in AERMOD.
- Convert SO_2 and NOx emissions into “equivalent” direct $PM_{2.5}$ emissions.
  - 100:1 ➔100 TPY SO_2 = 1 TPY direct $PM_{2.5}$
  - 10:1 ➔100 TPY SO_2 = 10 TPY direct $PM_{2.5}$
  - 1:1 ➔100 TPY SO_2 = 100 TPY direct $PM_{2.5}$
  - 0.5:1 ➔100 TPY SO_2 = 200 TPY direct $PM_{2.5}$
    - This is ~100% conversion of SO_2 to $(NH_4)_2SO_4$
- <u>Lower</u> $PM_{2.5}$ offset ratios will produce <u>more</u> secondary $PM_{2.5}$.

SECONDARY FORMATION IN AERMOD

- <u>Option 1</u>: Add SO_2 and NOx "equivalent" direct $PM_{2.5}$ emissions to the actual direct $PM_{2.5}$ emissions and run AERMOD
  - Allows for ratios that vary temporally
- <u>Option 2</u>: Calculate a percent increase in direct $PM_{2.5}$ emissions due to the addition of SO_2 and NOx "equivalent" direct $PM_{2.5}$ emissions and scale the AERMOD output for actual direct $PM_{2.5}$ emissions
  - Allows for ratios that vary spatially

MODEL SETUP

- Plant Washington PSD Permit Application
  - 850 MW Coal Fired Power Plant located in Washington County, GA (permit issued on April 8, 2010)
- 2002 MM5 Meteorology
- 2009 Emissions Used in Georgia's $PM_{2.5}$ SIPs
  - Added Plant Washington emissions
    - 4,200 TPY SO2, 1,817 TPY NOx, 6 TPY EC
    - Stack height = 137.16 meters
- CAMx with Flexi-nesting
  - 12-km/4-km/1.333-km
- Three sensitivity runs to calculate offset ratios
  - Zero-out stack emissions: (1) SO_2, (2) NOx, (3) EC

MODELED $PM_{2.5}$ OFFSET RATIOS

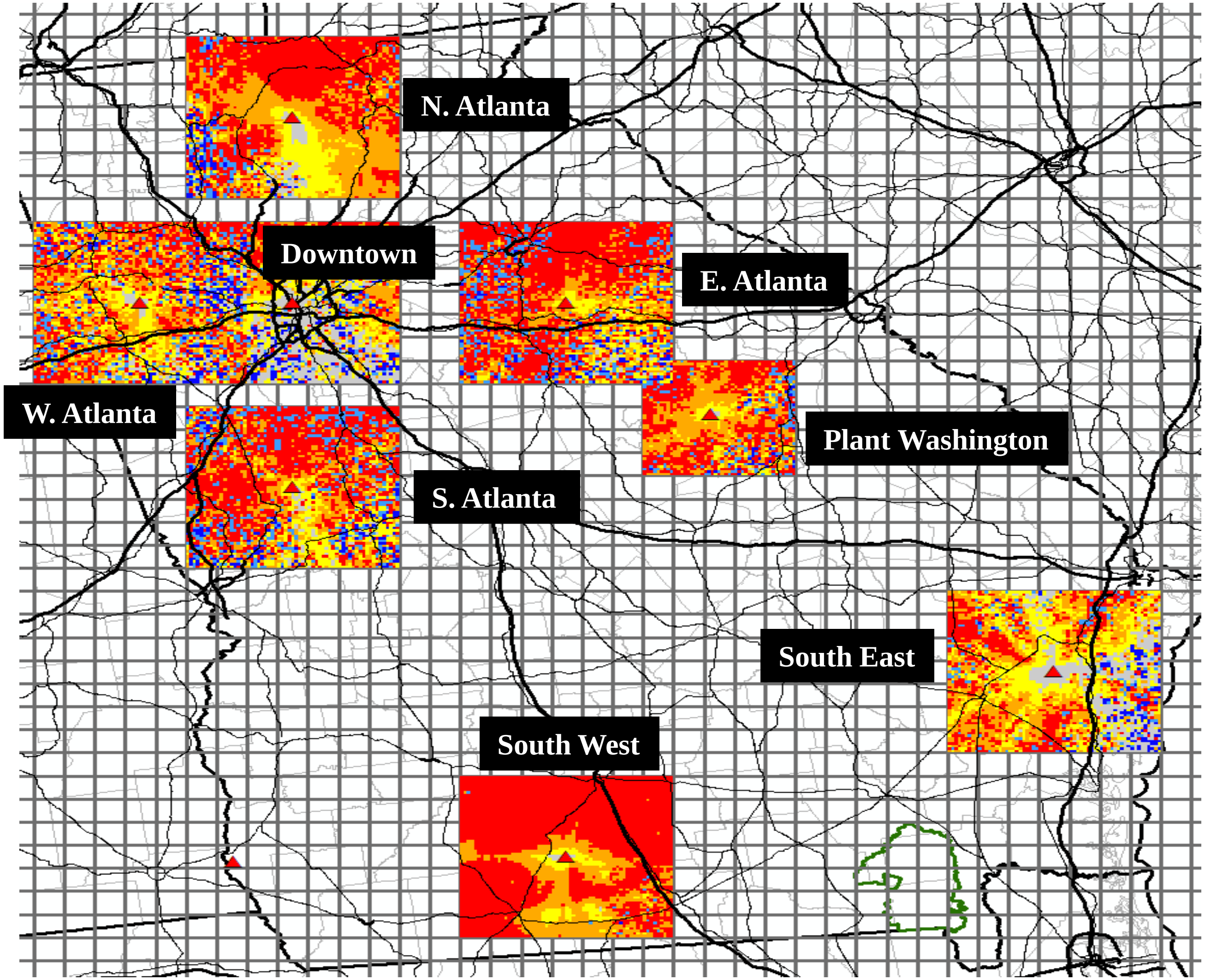
- Normalized Sensitivity (S)
  - $S_{SO2} = (\Delta PM2.5_{SO2}/\Delta TPY_{SO2})$
  - $S_{NOx} = (\Delta PM2.5_{NOx}/\Delta TPY_{NOx})$
  - $S_{PM2.5} = (\Delta PM2.5_{PM2.5}/\Delta TPY_{PM2.5})$

- $PM_{2.5}$ Offset Ratios (R)
  - $R_{SO2} = S_{PM2.5}/S_{SO2}$
  - $R_{NOx} = S_{PM2.5}/S_{NOx}$

SENSITIVITY RUNS

- Sensitivity runs were performed to evaluate how $PM_{2.5}$ offset ratios varied by:
  - Distance from the source
  - Season of the year
  - Location in the state
  - Stack height
  - Grid resolution

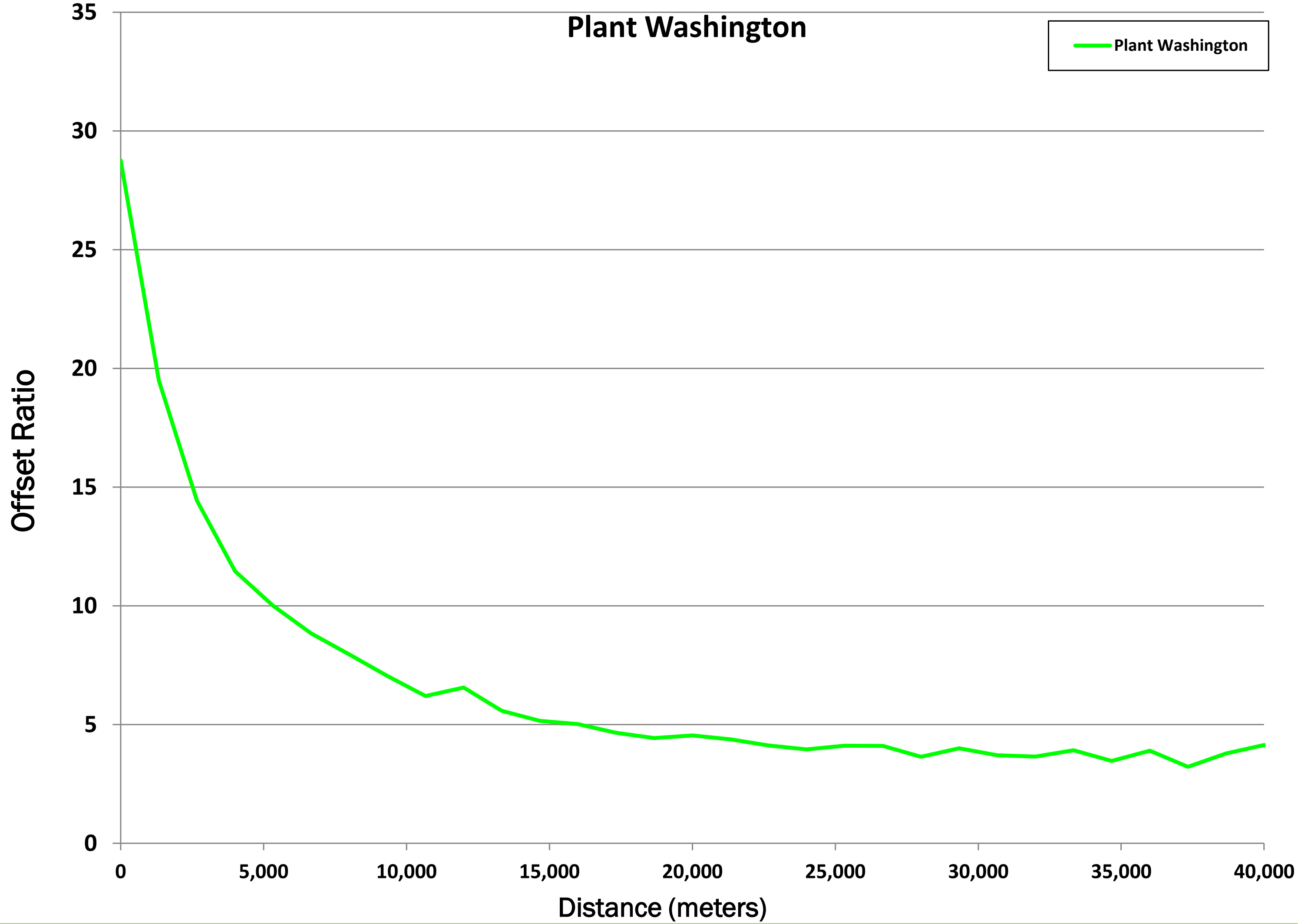
EIGHT MODELING DOMAINS



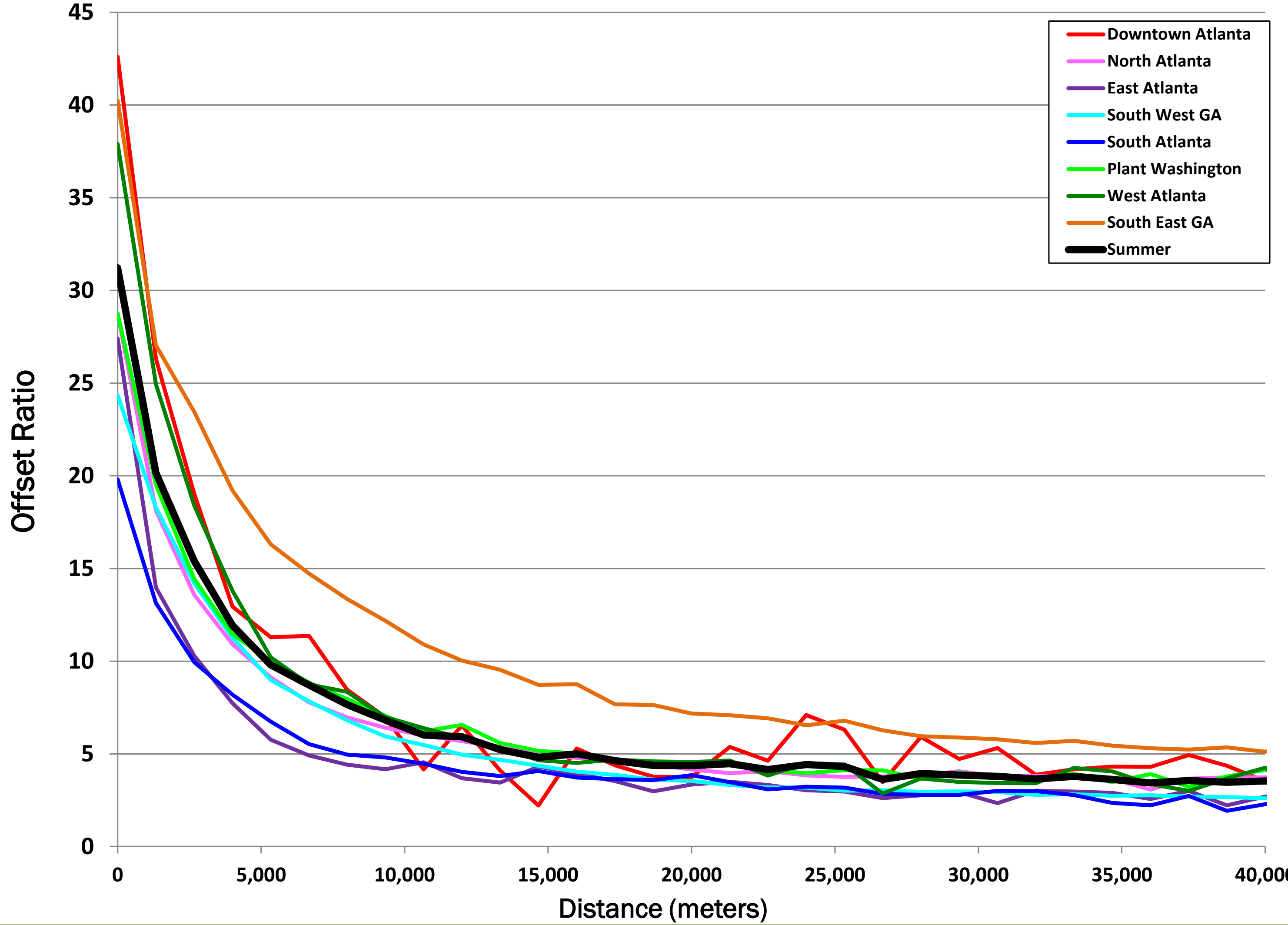
BINNED OFFSET RATIOS

- For each precursor (x2), season (x4), and location (x8):
  - Averaged S_{SO2}, S_{NOx}, and $S_{PM2.5}$ for all grid cells at a given distance
  - Calculated the average trading ratios (R_{SO2} and R_{NOx}) for each distance
- Placed trading ratios into three distance bins
  - <1 km, 1-4 km, >4 km

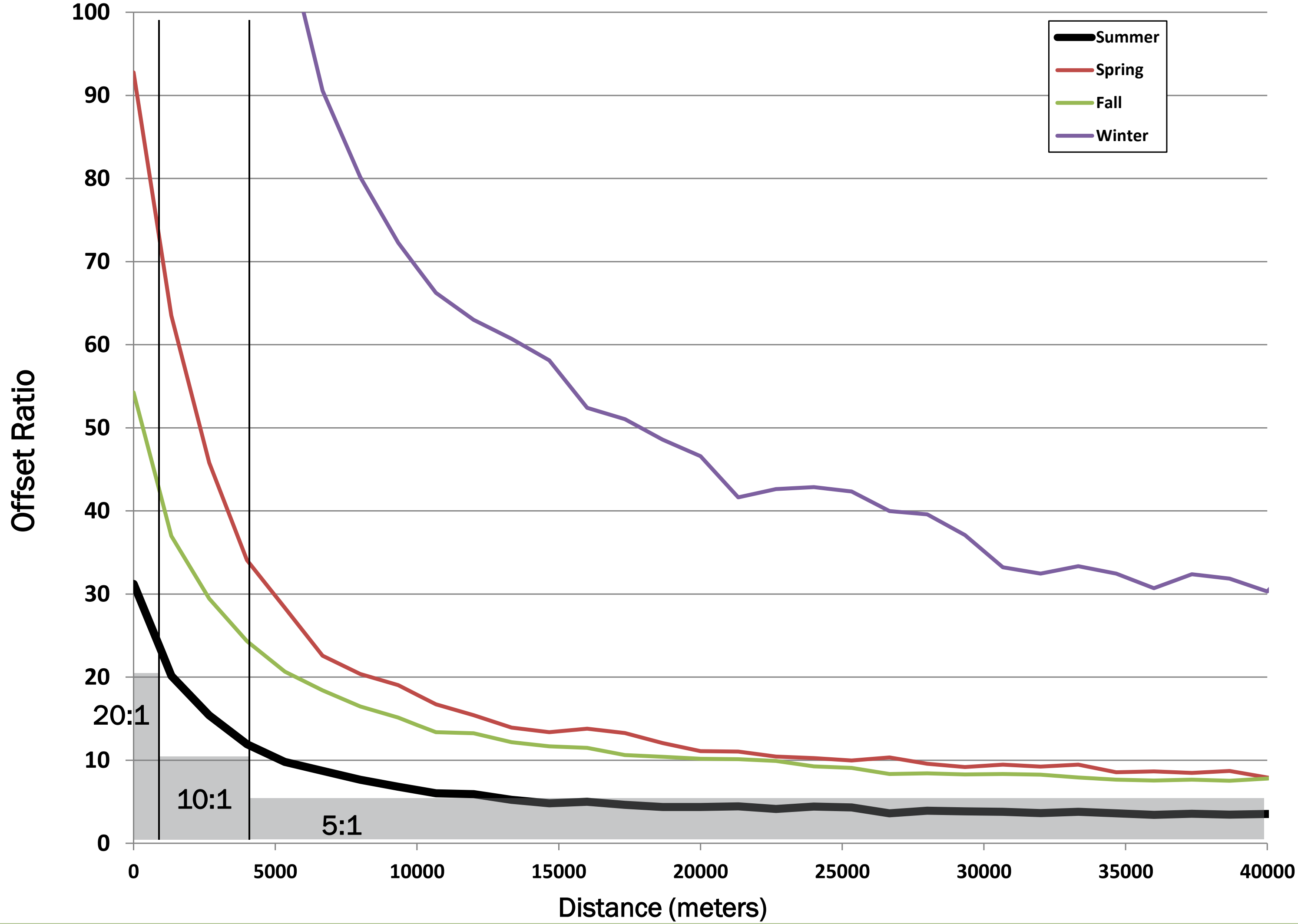
SO_2 OFFSET RATIOS - SUMMER



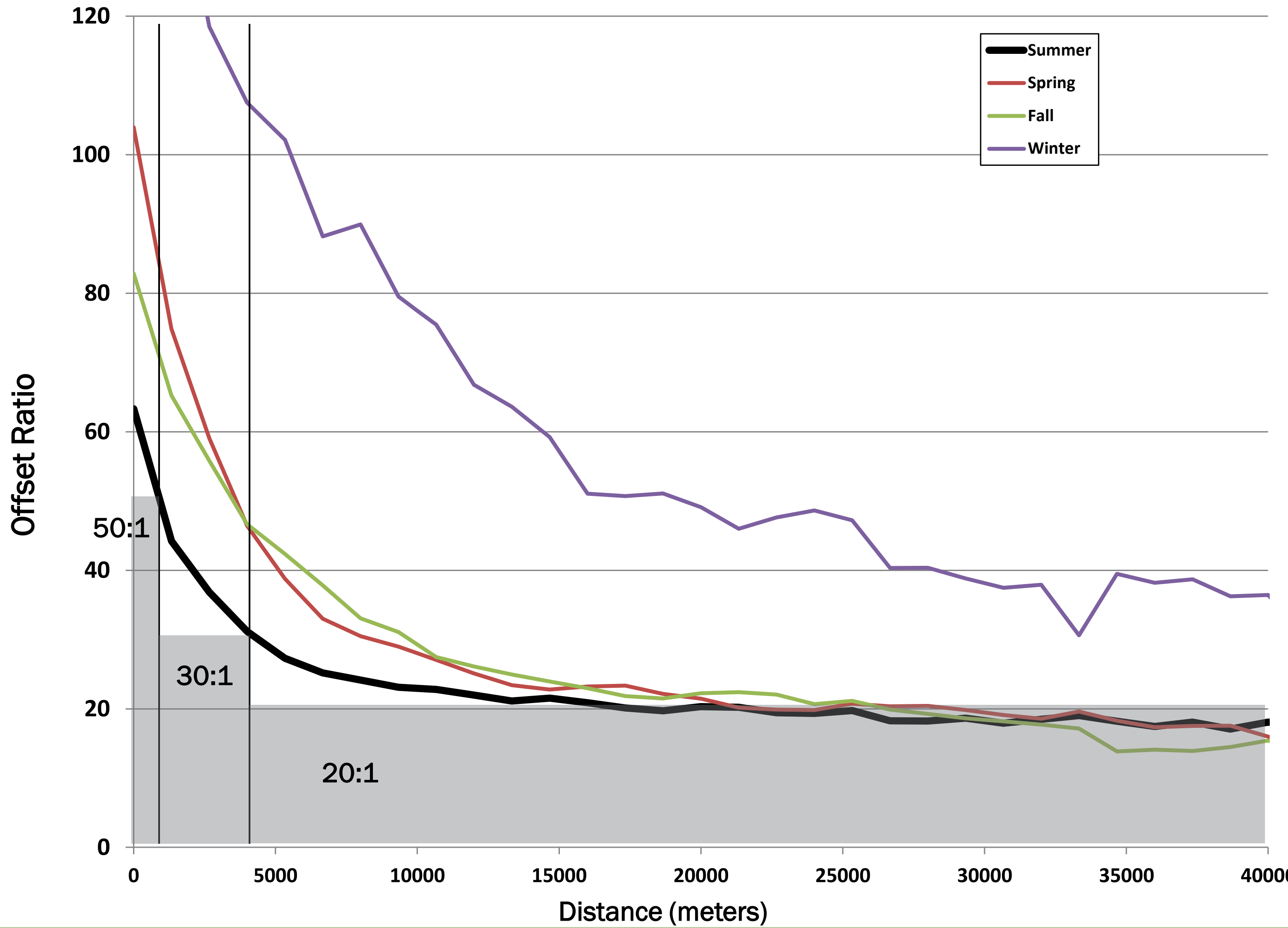
SO_2 OFFSET RATIOS - SUMMER



SO_2 OFFSET RATIOS – ALL SEASONS



NOx OFFSET RATIOS – ALL SEASONS



TIERED APPROACH

- Used a tiered approach starting with the most conservative offset ratios and easiest to apply:
  - Tier 1
    - SO_2 and NOx offset ratios from summer at distance > 4 km
  - Tier 2
    - SO_2 and NOx offset ratios from summer that vary with distance (3 bins)
  - Tier 3
    - Application of SO_2 and NOx offset ratios that are location specific and vary by quarter and by distance

Distance	SO_2	NOx
< 1 km	20:1	50:1
1 – 4 km	10:1	30:1
> 4 km	5:1	20:1

EXAMPLE #1

- Direct $PM_{2.5}$ emissions = 118.30 TYP
- SO_2 emissions = 190.93 TPY
- NOx emissions = 340.65 TPY

- $PM_{2.5}$ Scaling Factor =

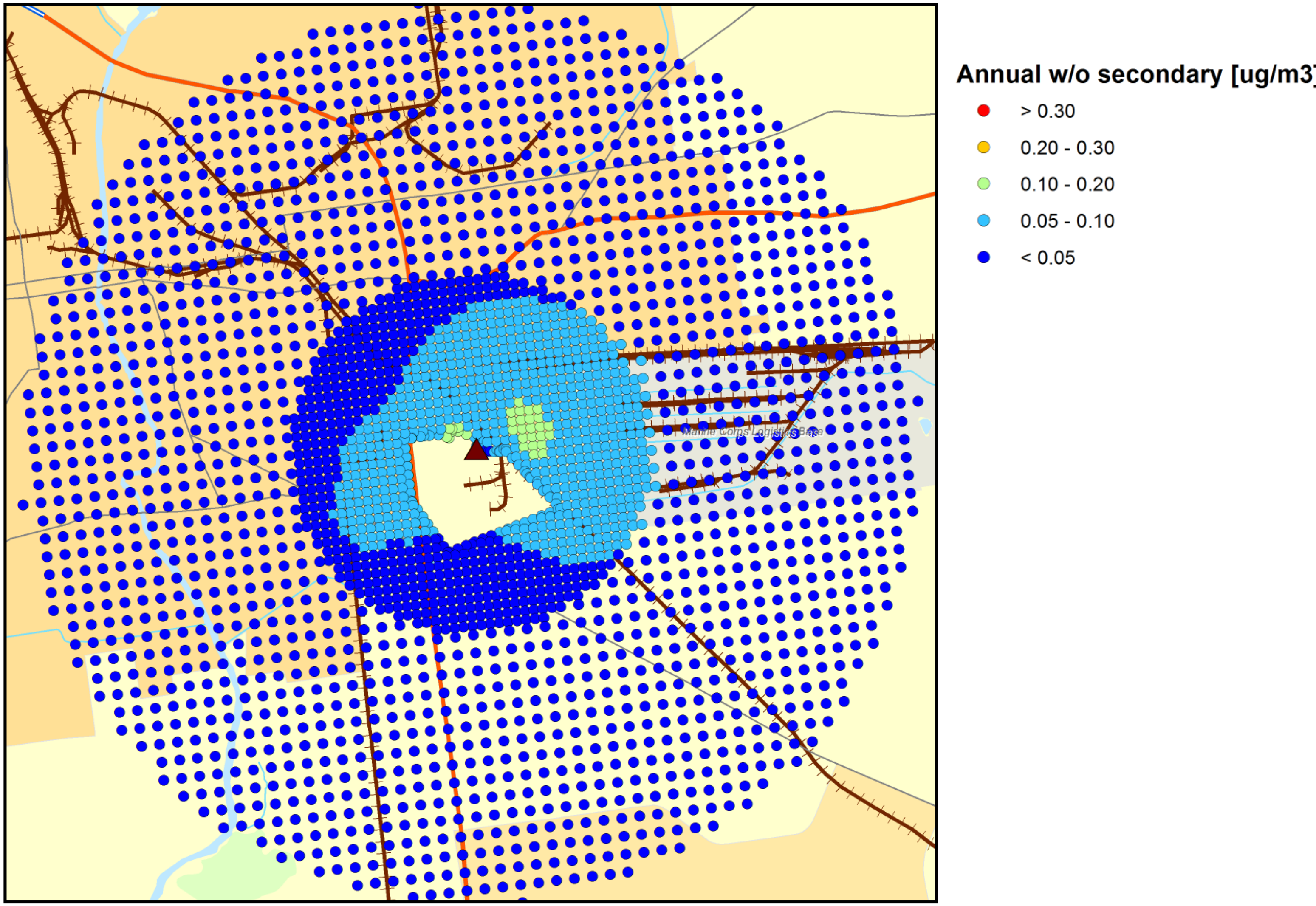
$$\frac{(SO2\ TPY/SO2\ Ratio) + (NOx\ TPY/NOx\ Ratio) + PM2.5\ TPY}{PM2.5\ TPY}$$

Distance	SO_2 Ratio	NOx Ratio	Scaling Factor
< 1 km	20	50	1.138
1 - 4 km	10	30	1.257
> 4 km	5	20	1.467

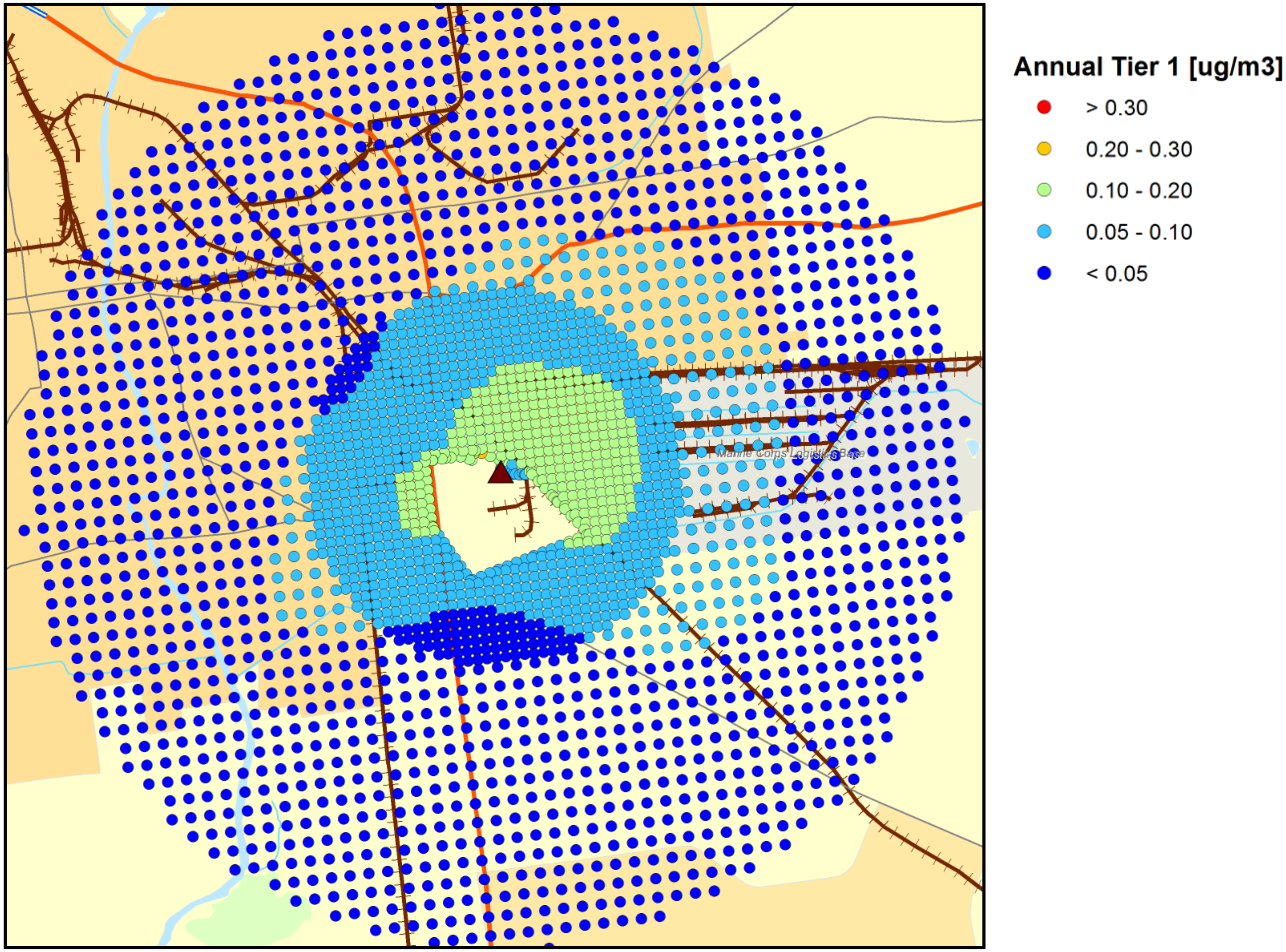
(Tier 2)

(Tier 1)

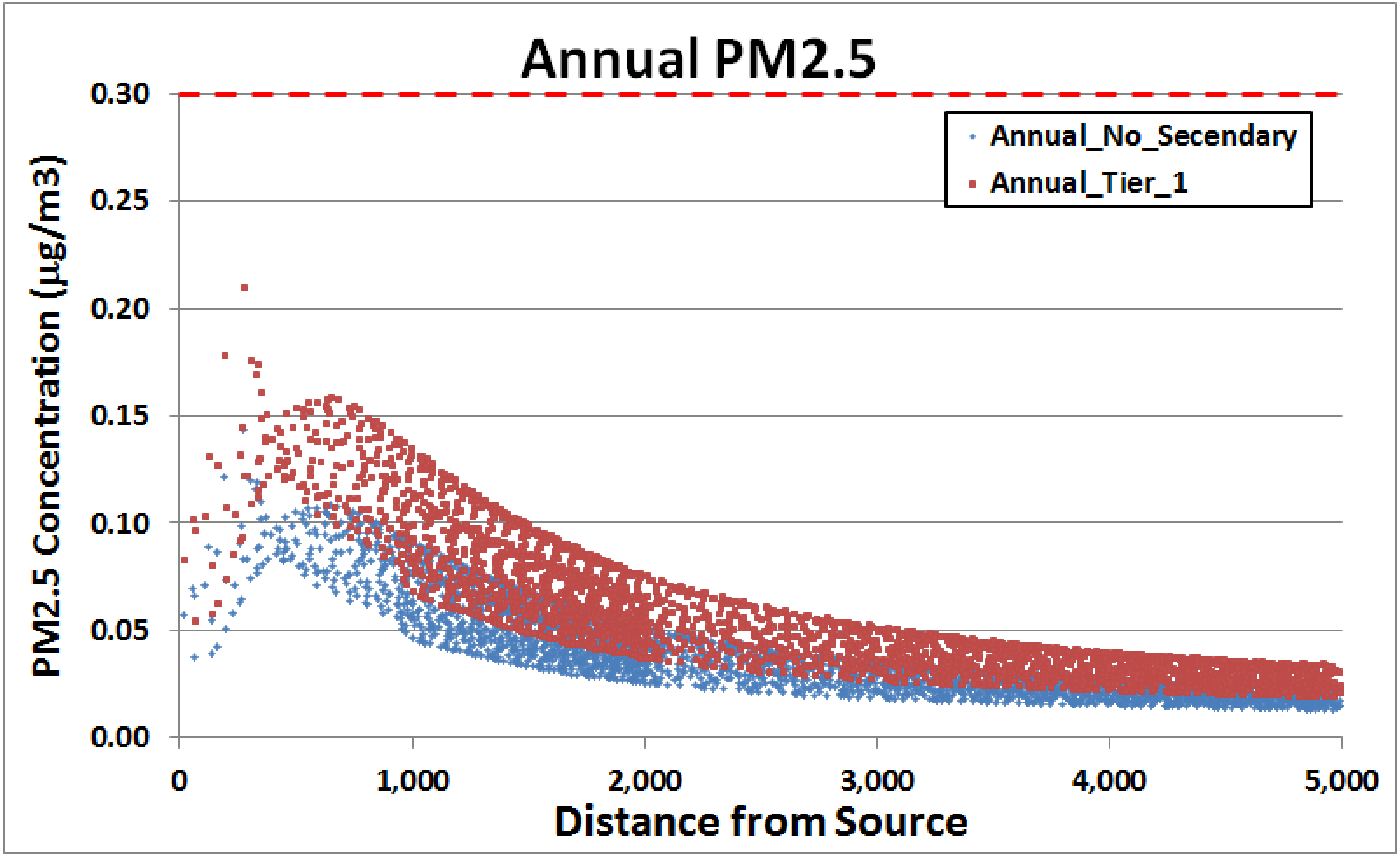
ANNUAL $PM_{2.5}$ – NO SECONDARY



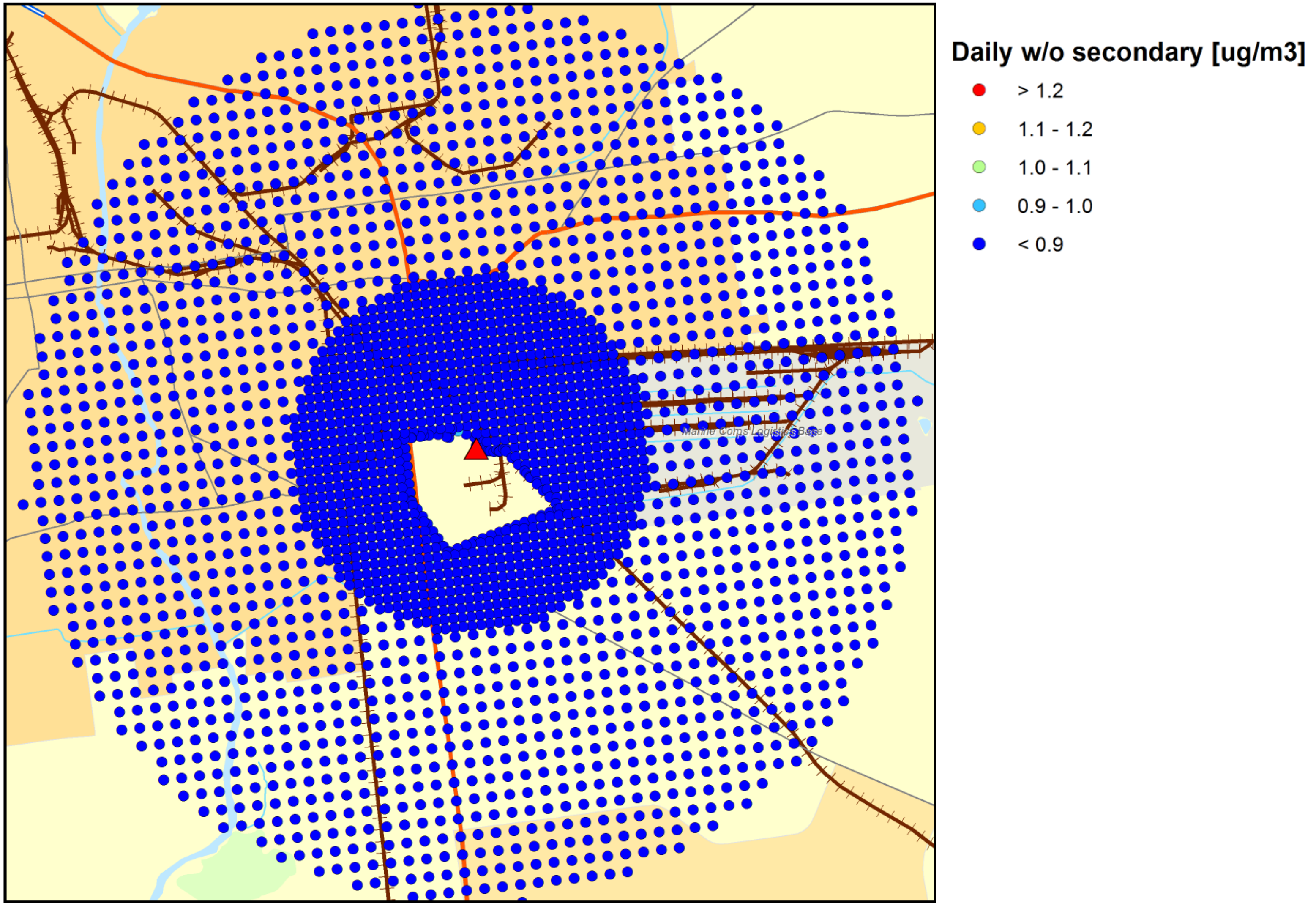
ANNUAL $PM_{2.5}$ – TIER 1



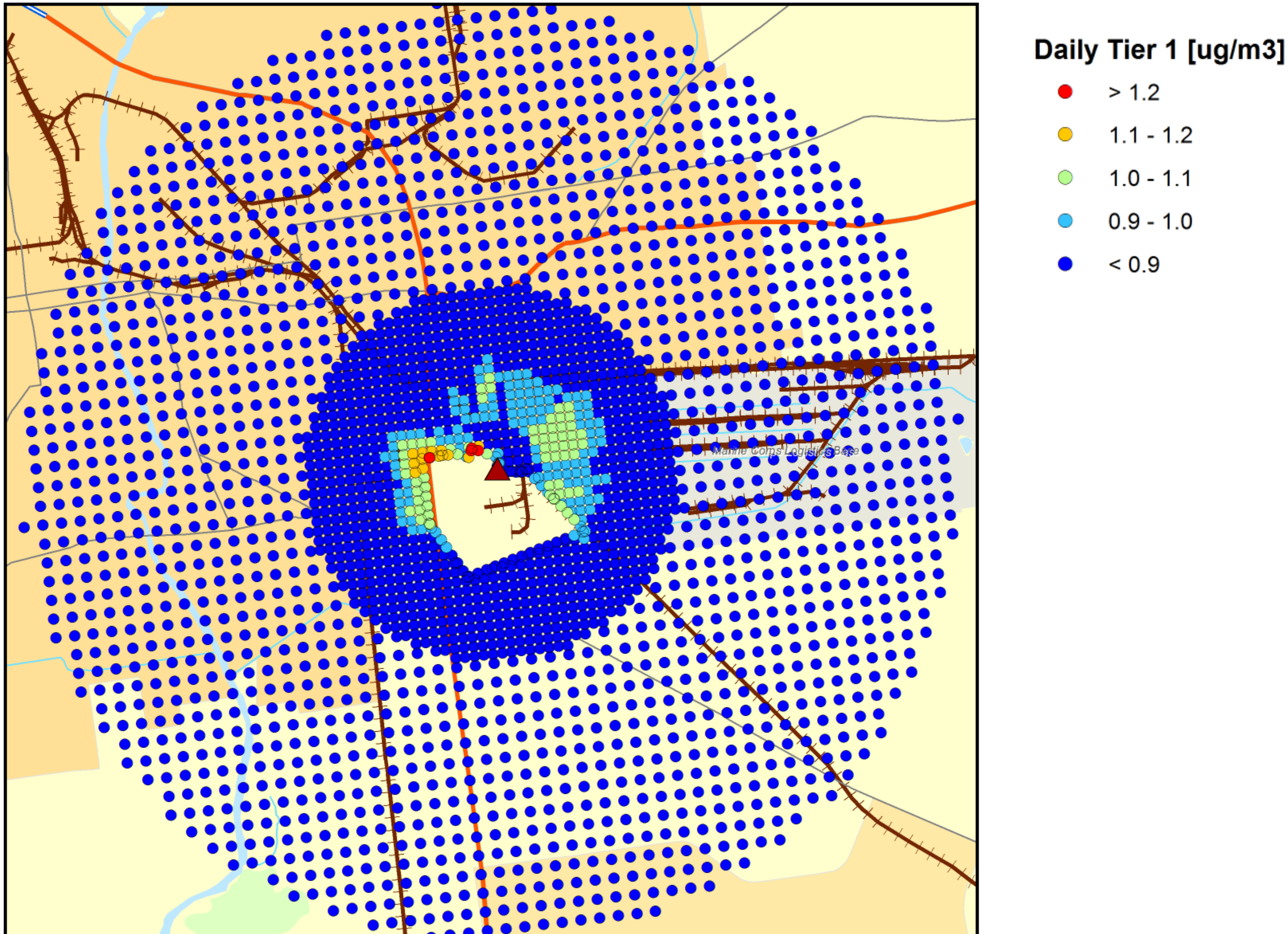
ANNUAL $PM_{2.5}$ vs. SIL



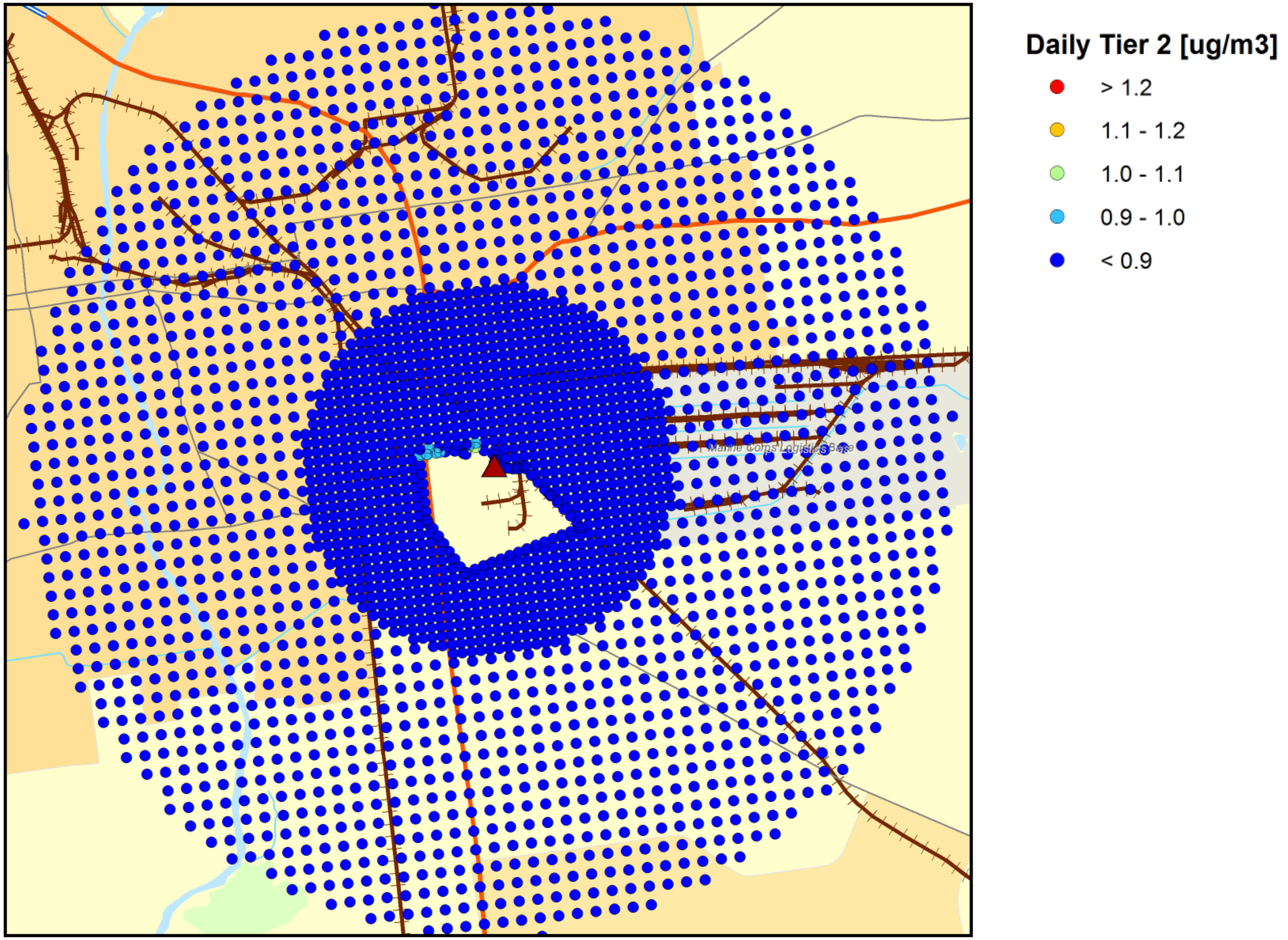
DAILY $PM_{2.5}$ – NO SECONDARY



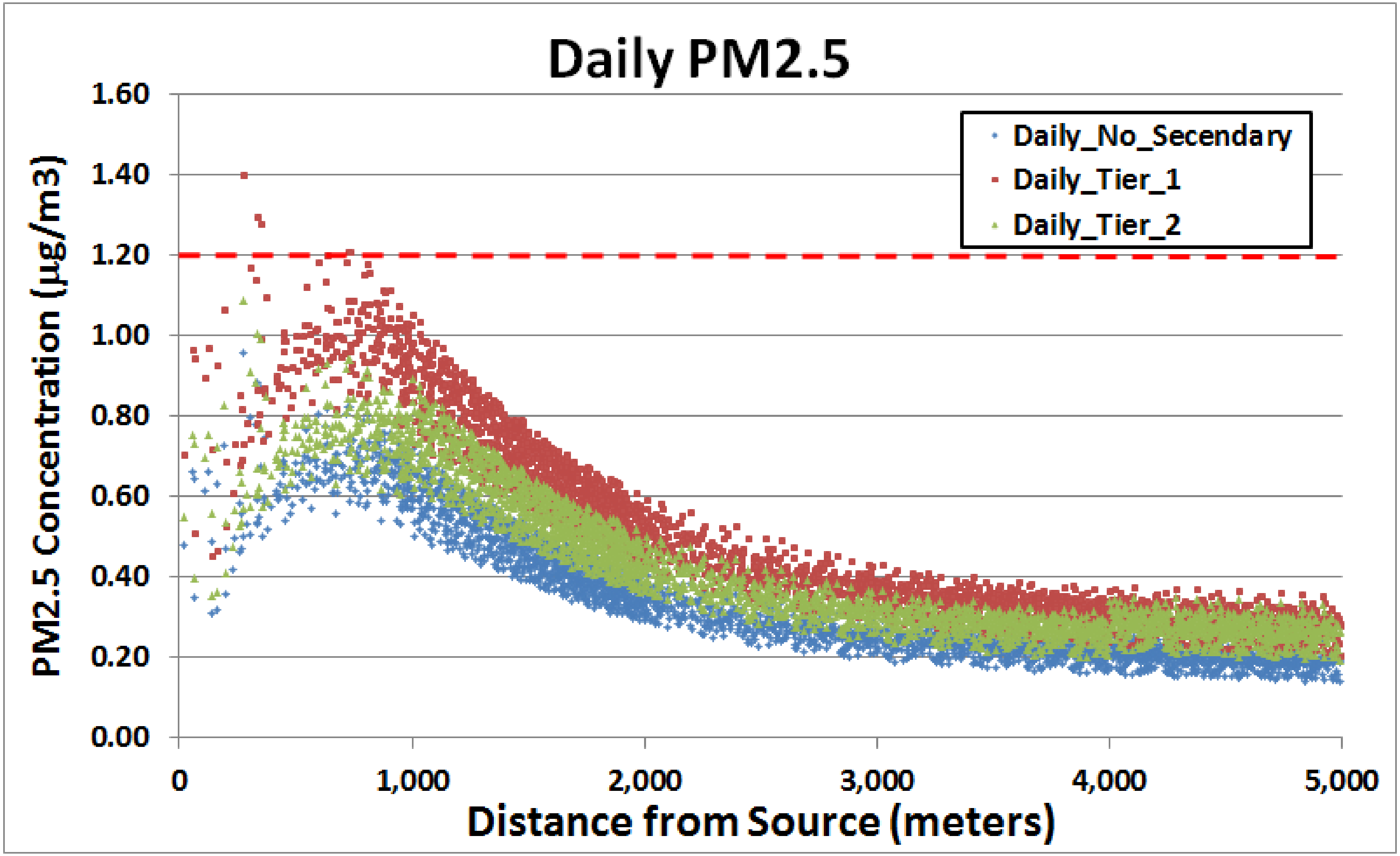
DAILY $PM_{2.5}$ – TIER 1



DAILY $PM_{2.5}$ – TIER 2



DAILY $PM_{2.5}$ vs. SIL



EXAMPLE #2

- Direct $PM_{2.5}$ emissions = 46.9 TYP
- SO_2 emissions = 0.49 TPY
- NOx emissions = 72.1 TPY

- $PM_{2.5}$ Scaling Factor =

$$\frac{\text{(SO2 TPY/SO2 Ratio) + (NOx TPY/NOx Ratio) + PM2.5 TPY}}{\text{PM2.5 TPY}}$$

Distance	SO_2 Ratio	NOx Ratio	Scaling Factor
< 1 km	~~20~~	50	1.031
1 - 4 km	~~1~~	30	1.051 (Tier 2)
> 4 km	~~5~~	20	1.076 (Tier 1)

EXAMPLE #3

- Direct $PM_{2.5}$ emissions = 46.9 TYP
- SO_2 emissions = 72.1 TPY
- NOx emissions = 72.1 TPY

- $PM_{2.5}$ Scaling Factor =

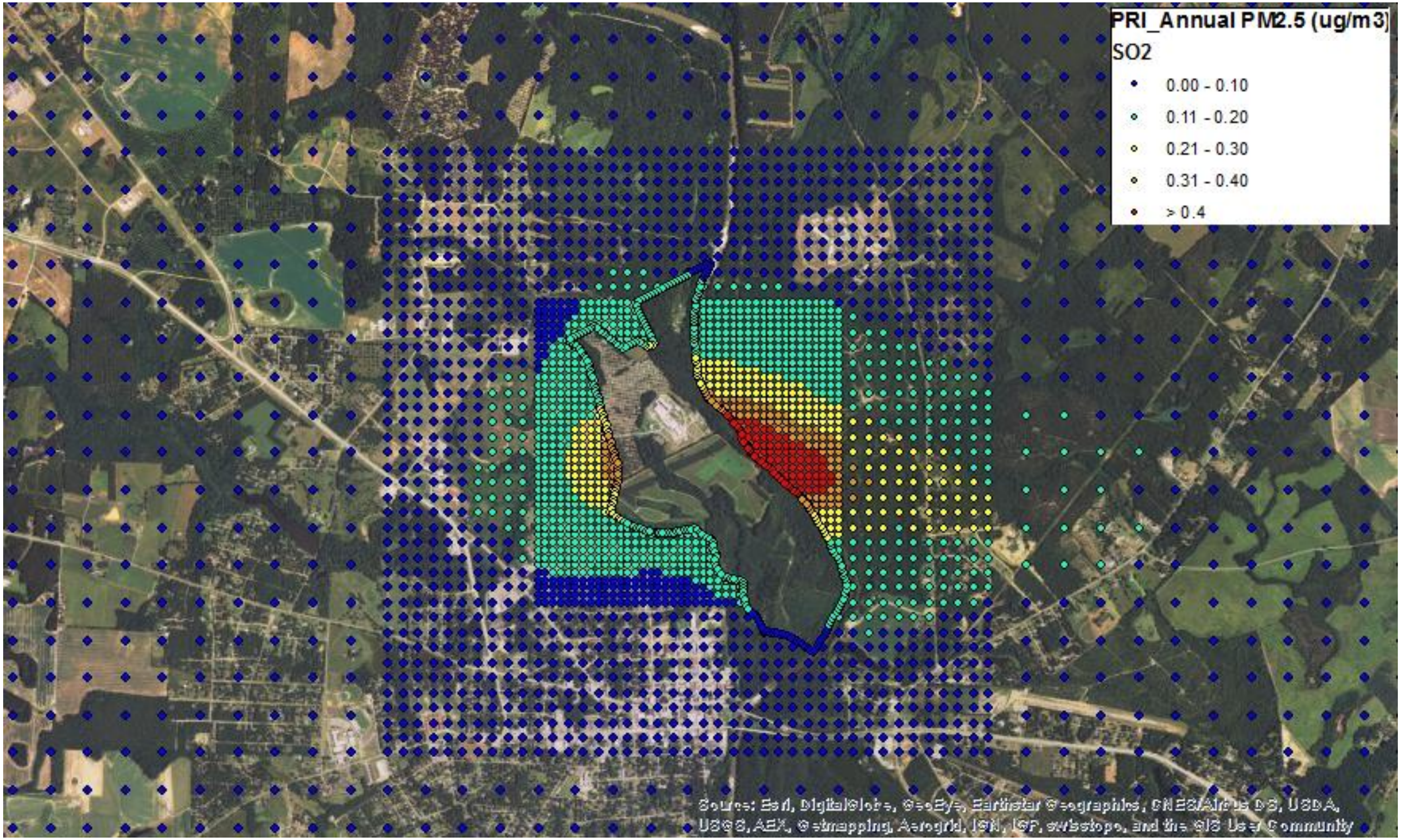
$$\frac{(SO2\ TPY/SO2\ Ratio) + (NOx\ TPY/NOx\ Ratio) + PM2.5\ TPY}{PM2.5\ TPY}$$

Distance	SO_2 Ratio	NOx Ratio	Scaling Factor
< 1 km	20	50	1.108
1 - 4 km	10	30	1.205
> 4 km	5	20	1.384

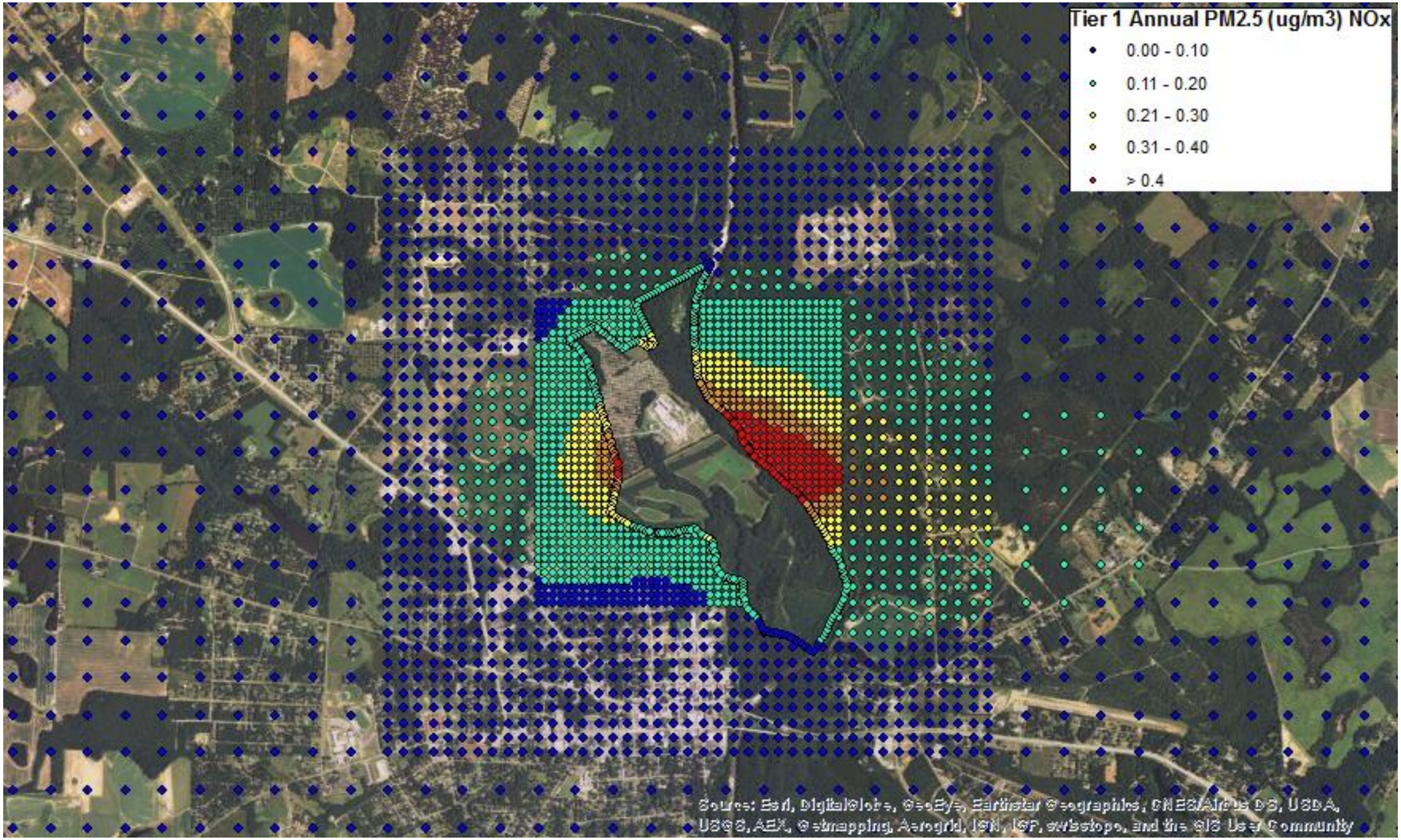
(Tier 2)

(Tier 1)

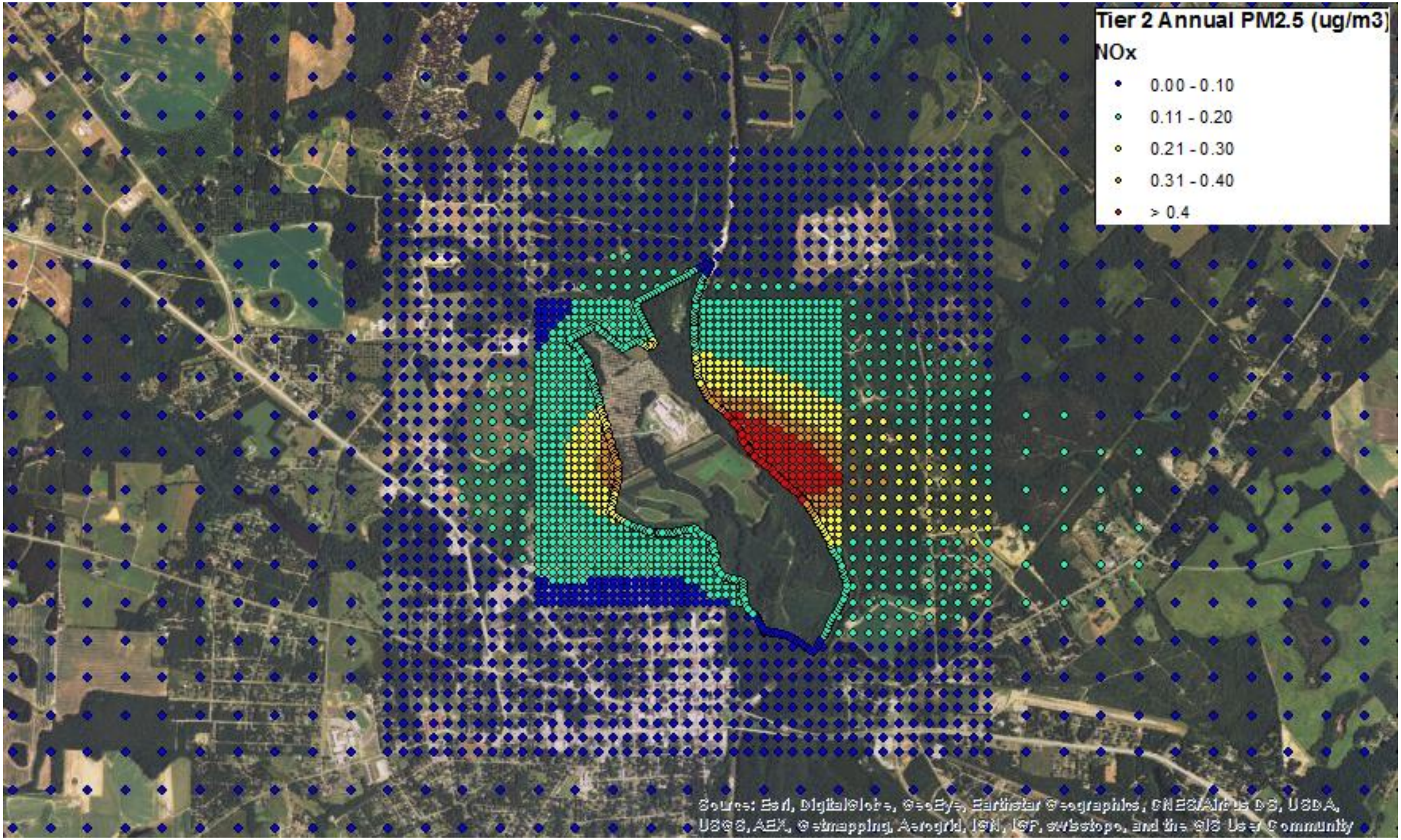
ANNUAL $PM_{2.5}$ – NO SECONDARY IMPACTS



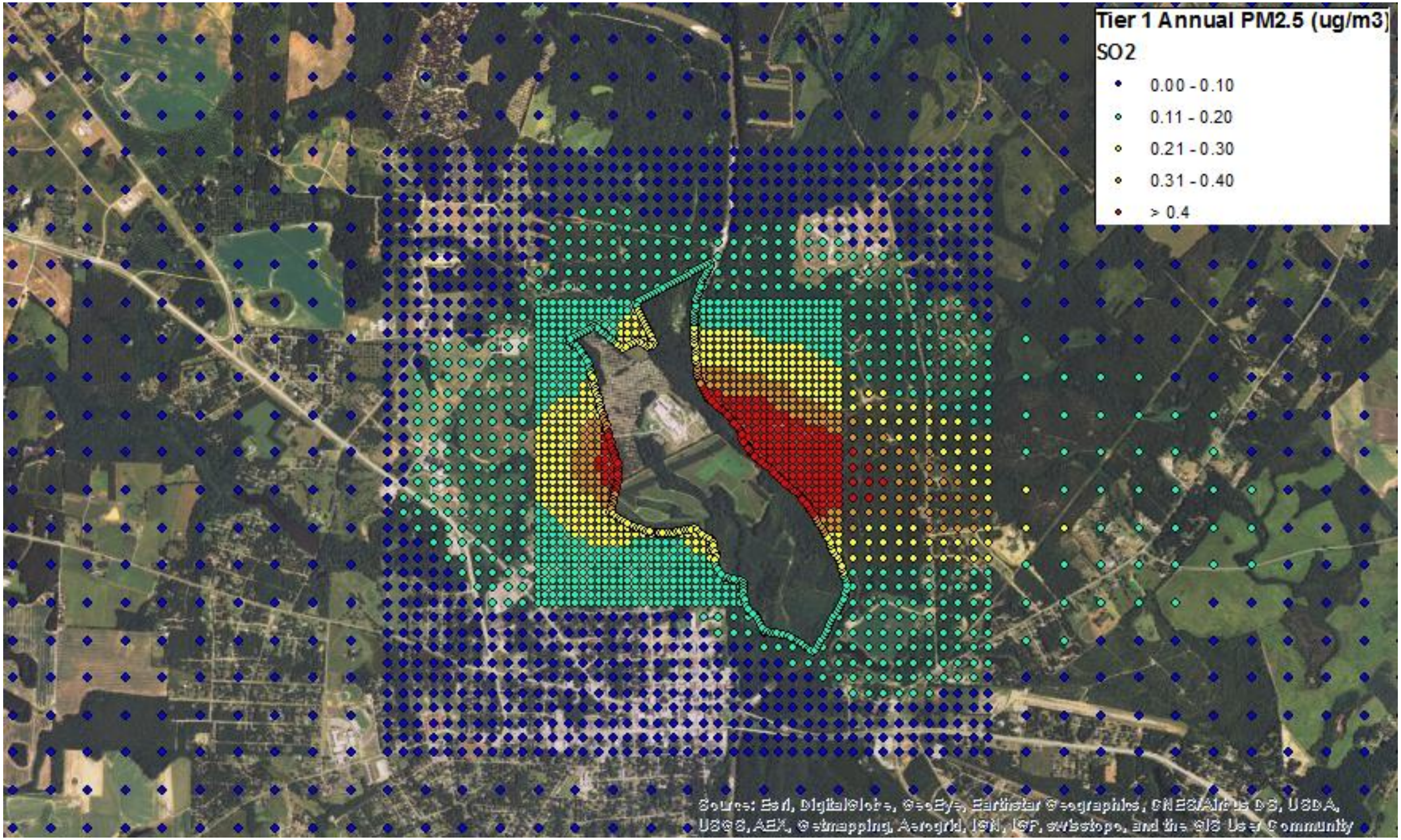
ANNUAL $PM_{2.5}$ – TIER 1 (EXAMPLE #2)



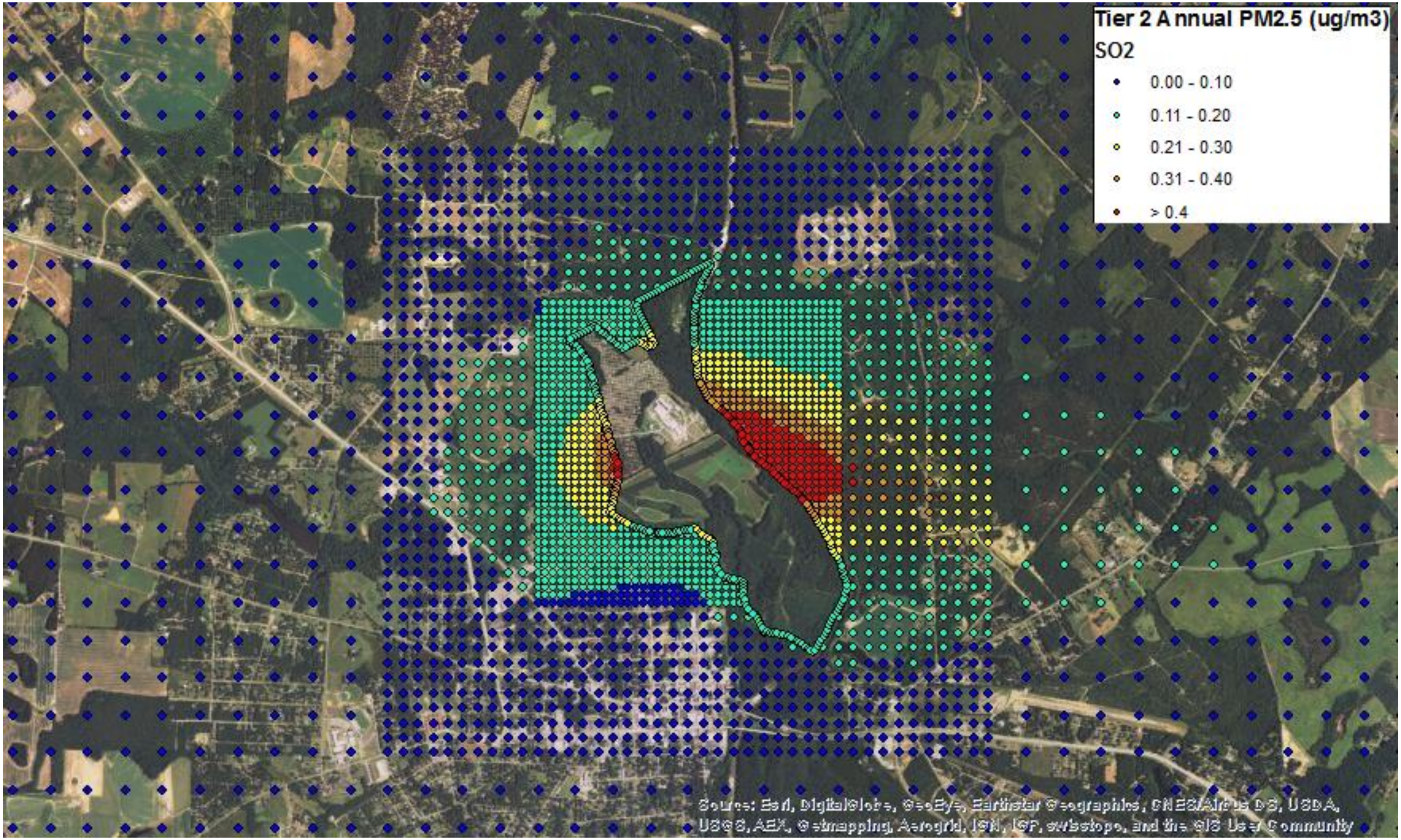
ANNUAL $PM_{2.5}$ – TIER 2 (EXAMPLE #2)



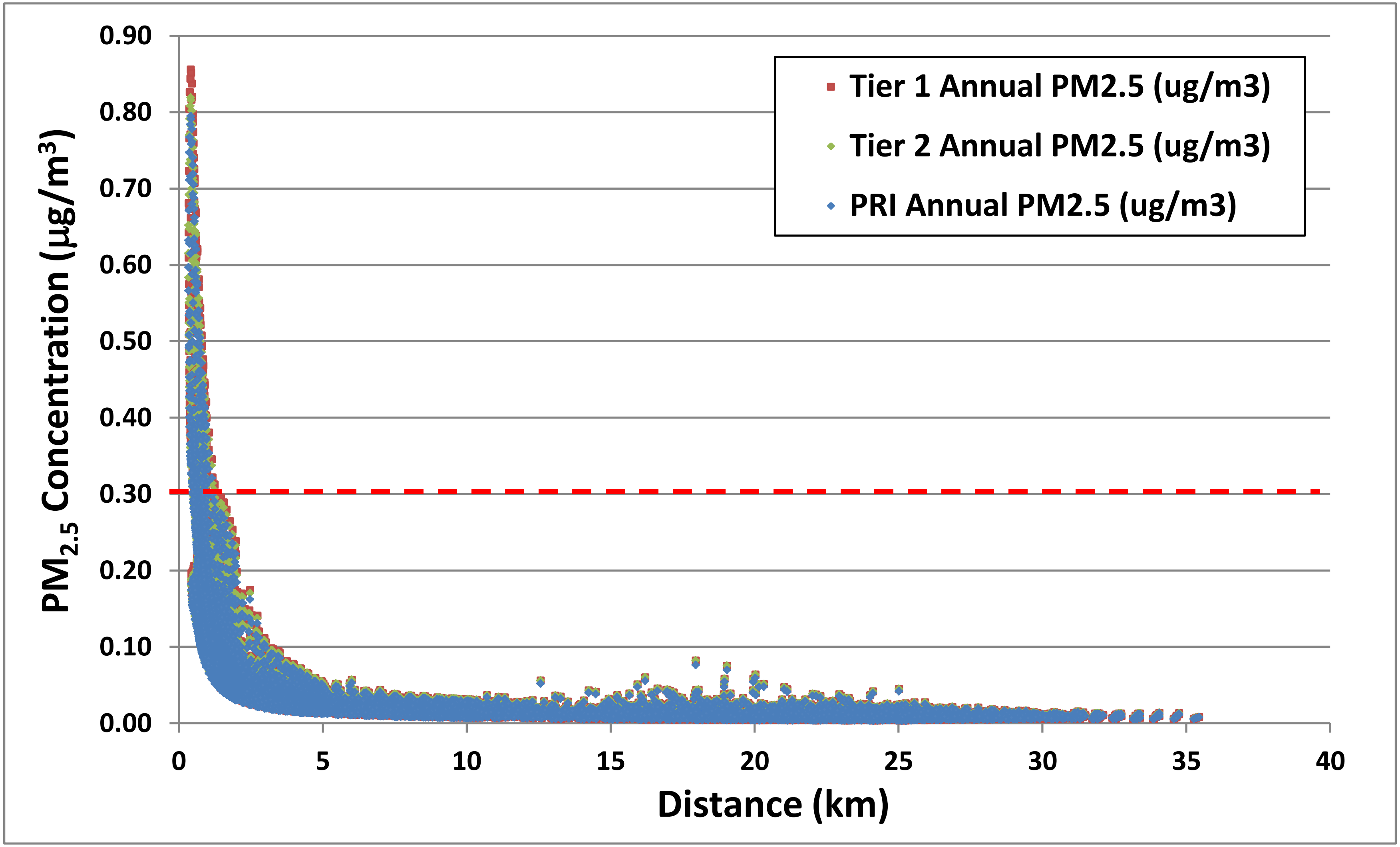
ANNUAL $PM_{2.5}$ – TIER 1 (EXAMPLE #3)



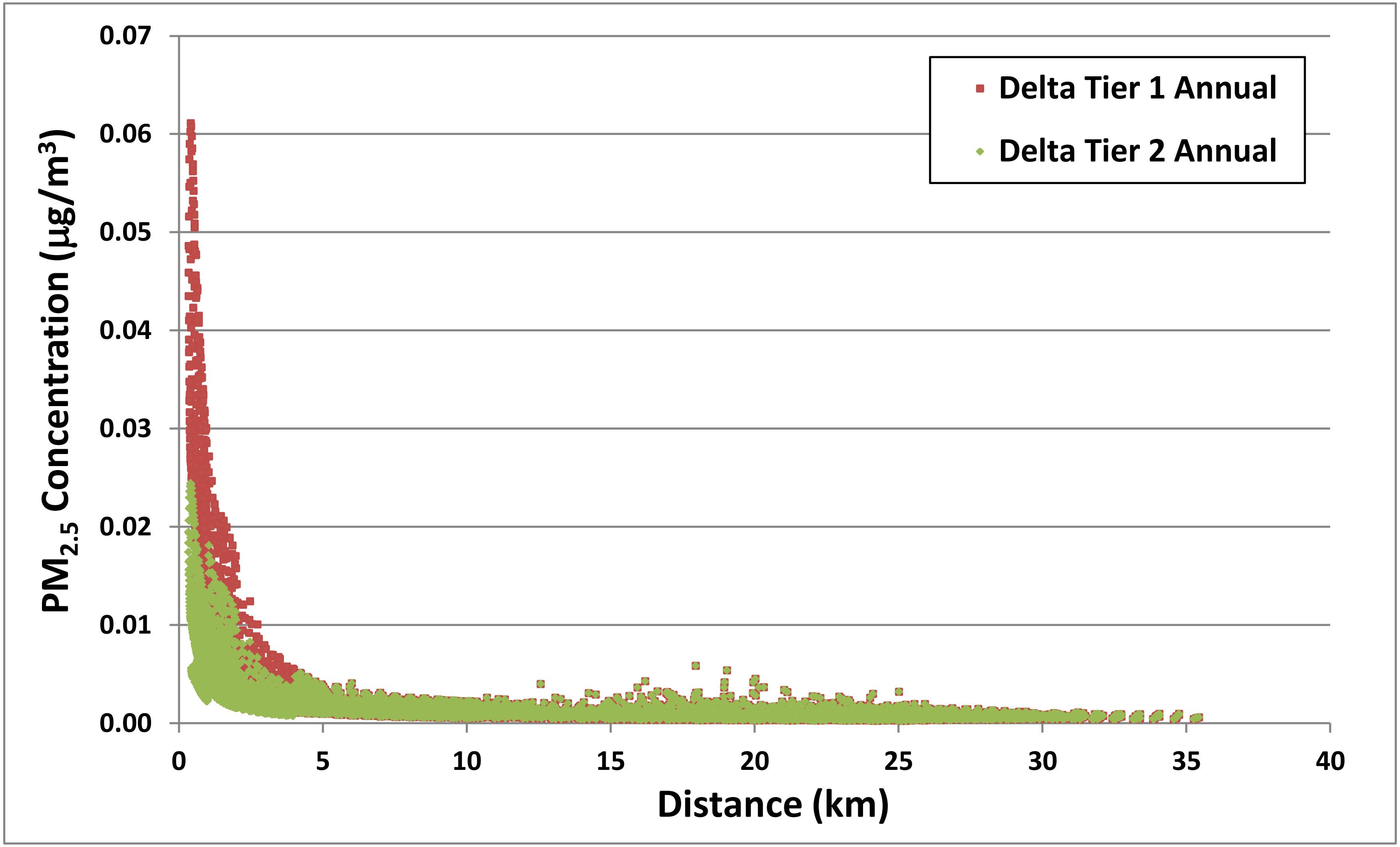
ANNUAL $PM_{2.5}$ – TIER 2 (EXAMPLE #3)



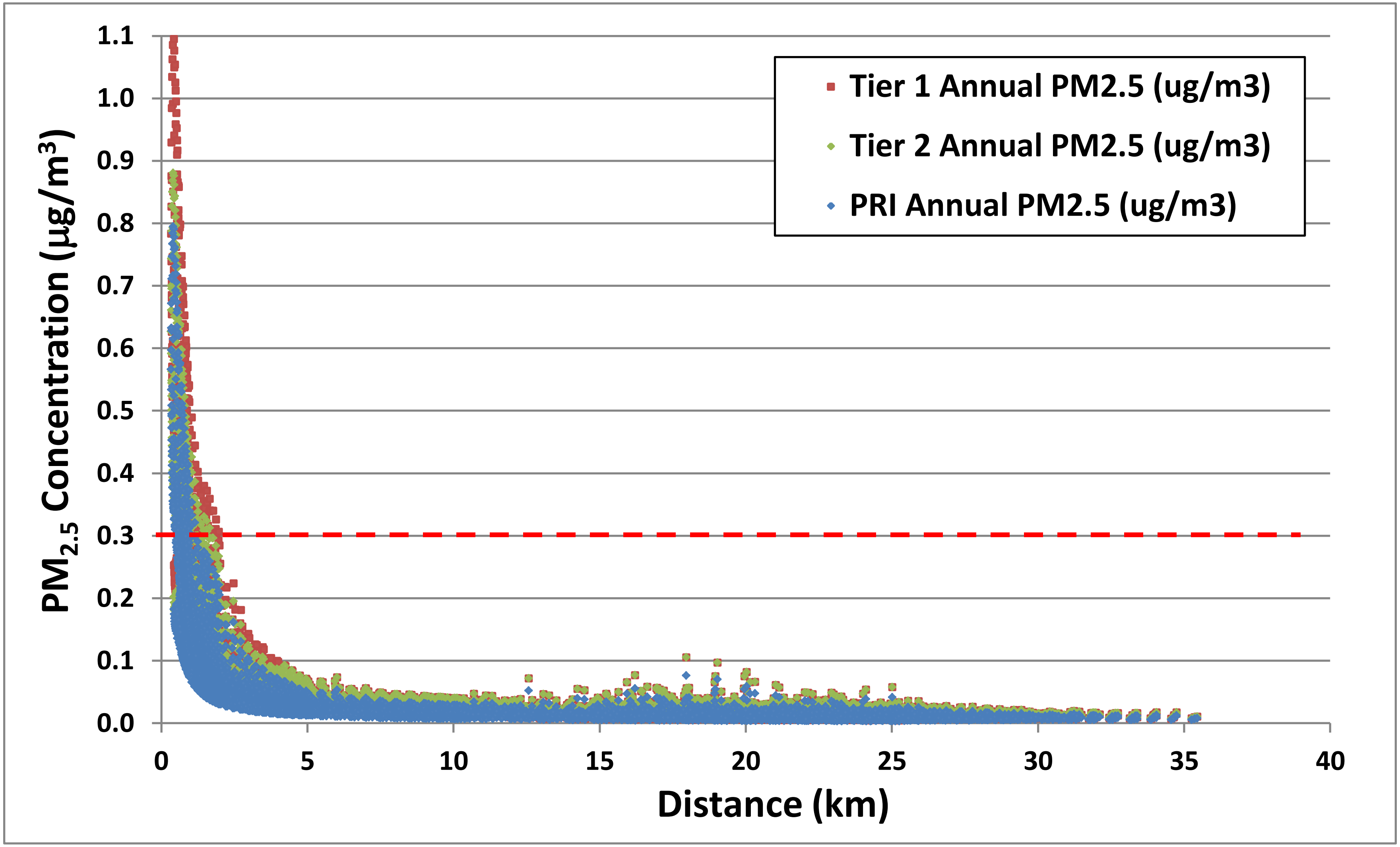
EXAMPLE #2 - ANNUAL $PM_{2.5}$ VS. SIL



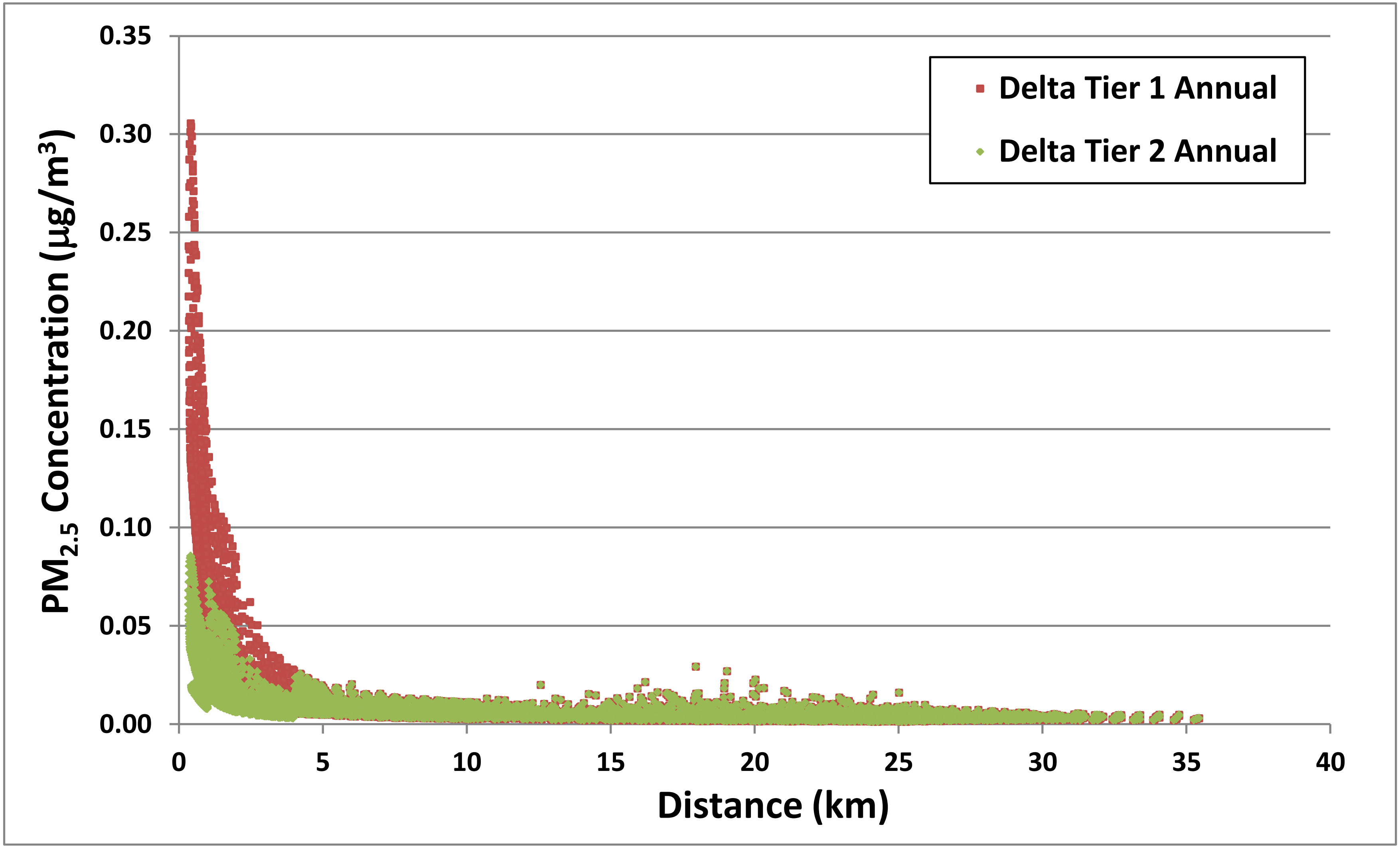
EXAMPLE #2 – ANNUAL SECONDARY $PM_{2.5}$



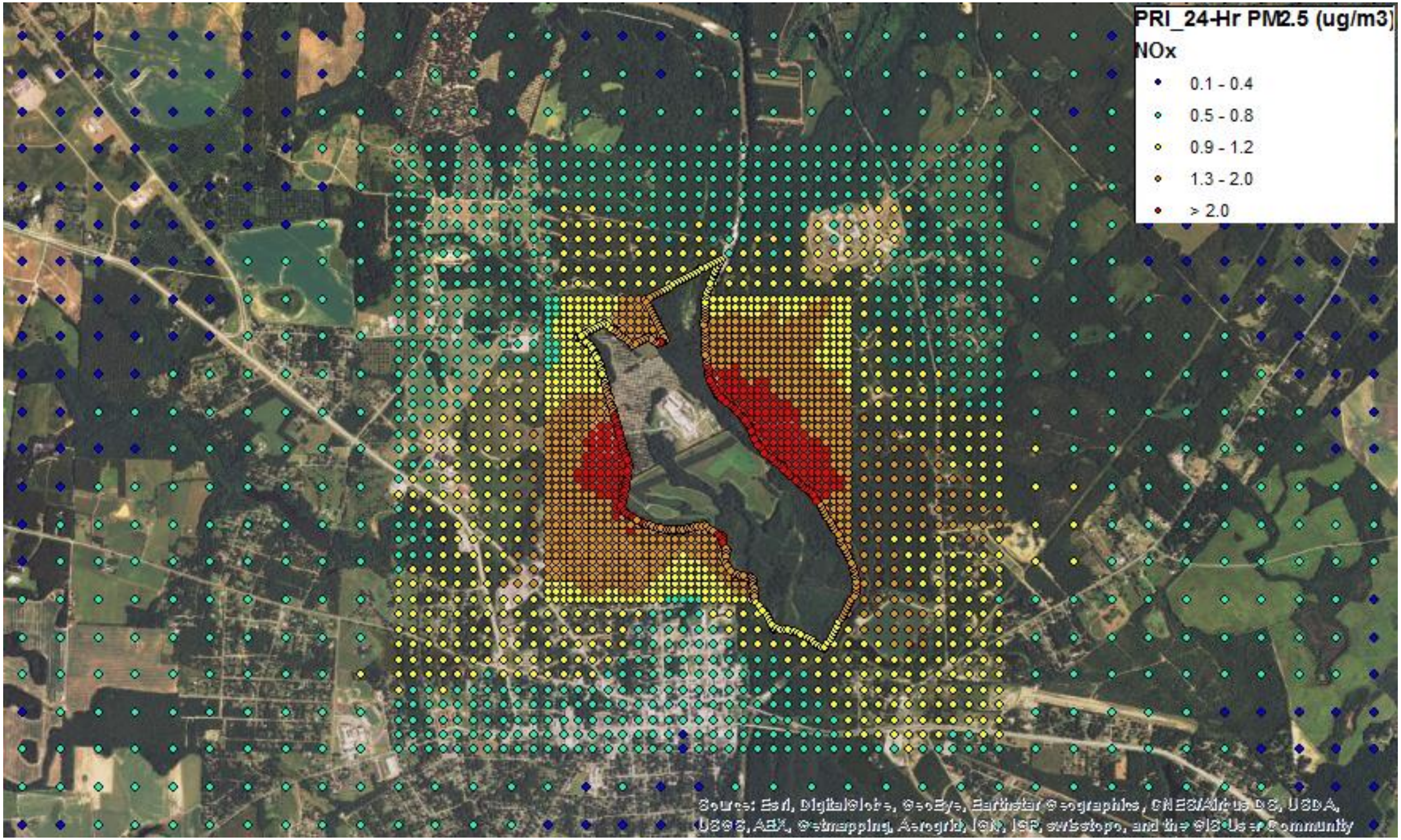
EXAMPLE #3 - ANNUAL $PM_{2.5}$ VS. SIL



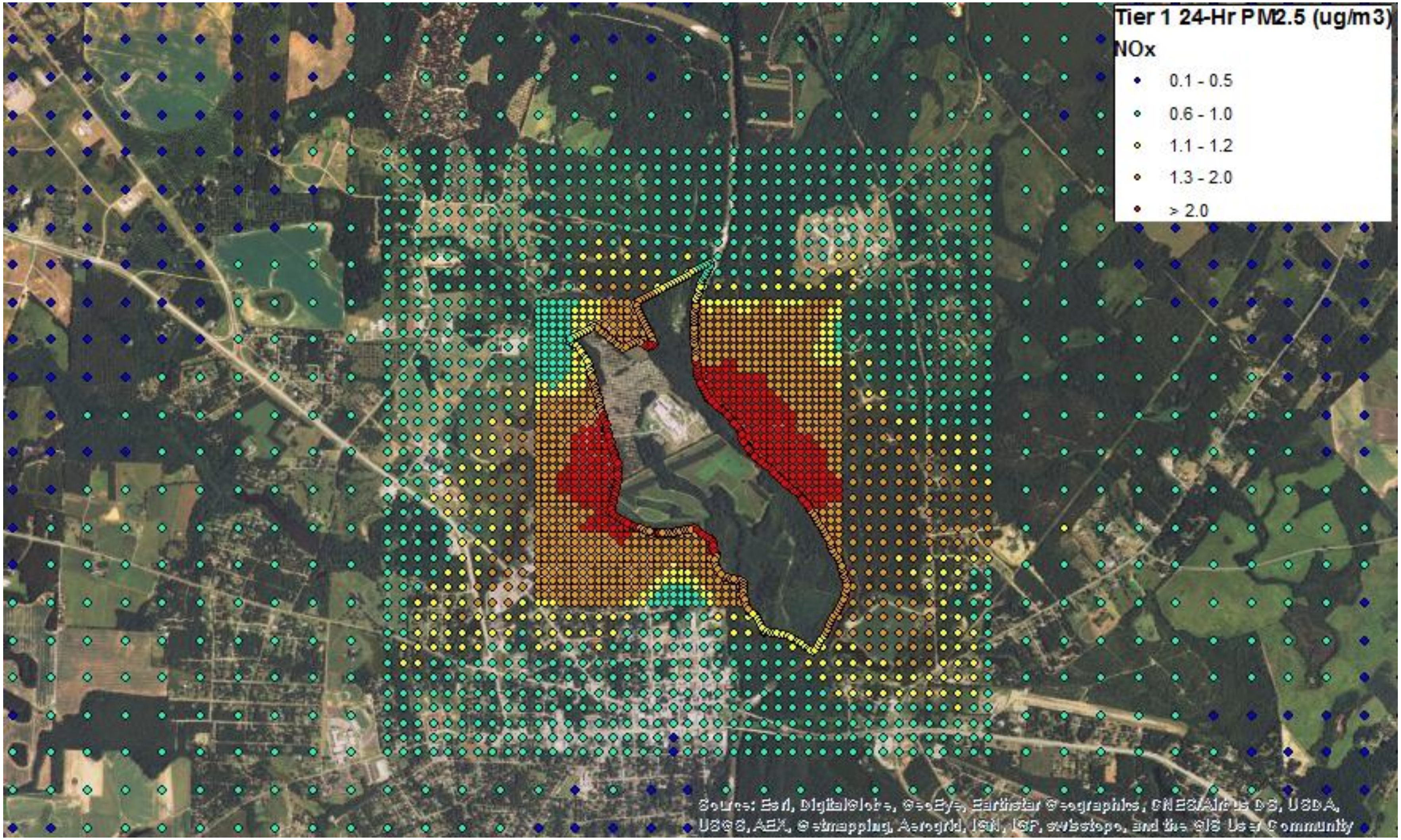
EXAMPLE #3 – ANNUAL SECONDARY $PM_{2.5}$



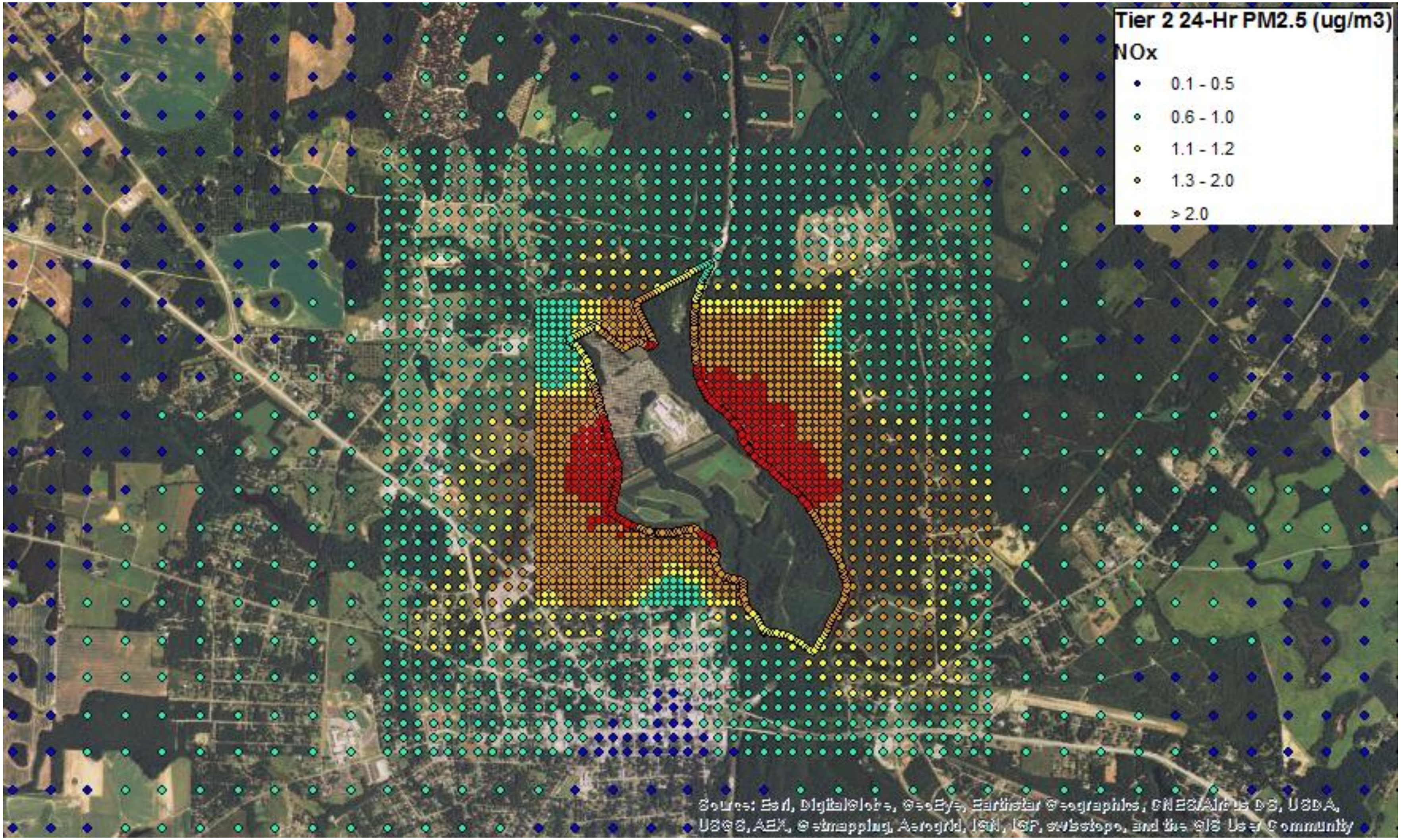
DAILY $PM_{2.5}$ – NO SECONDARY IMPACTS



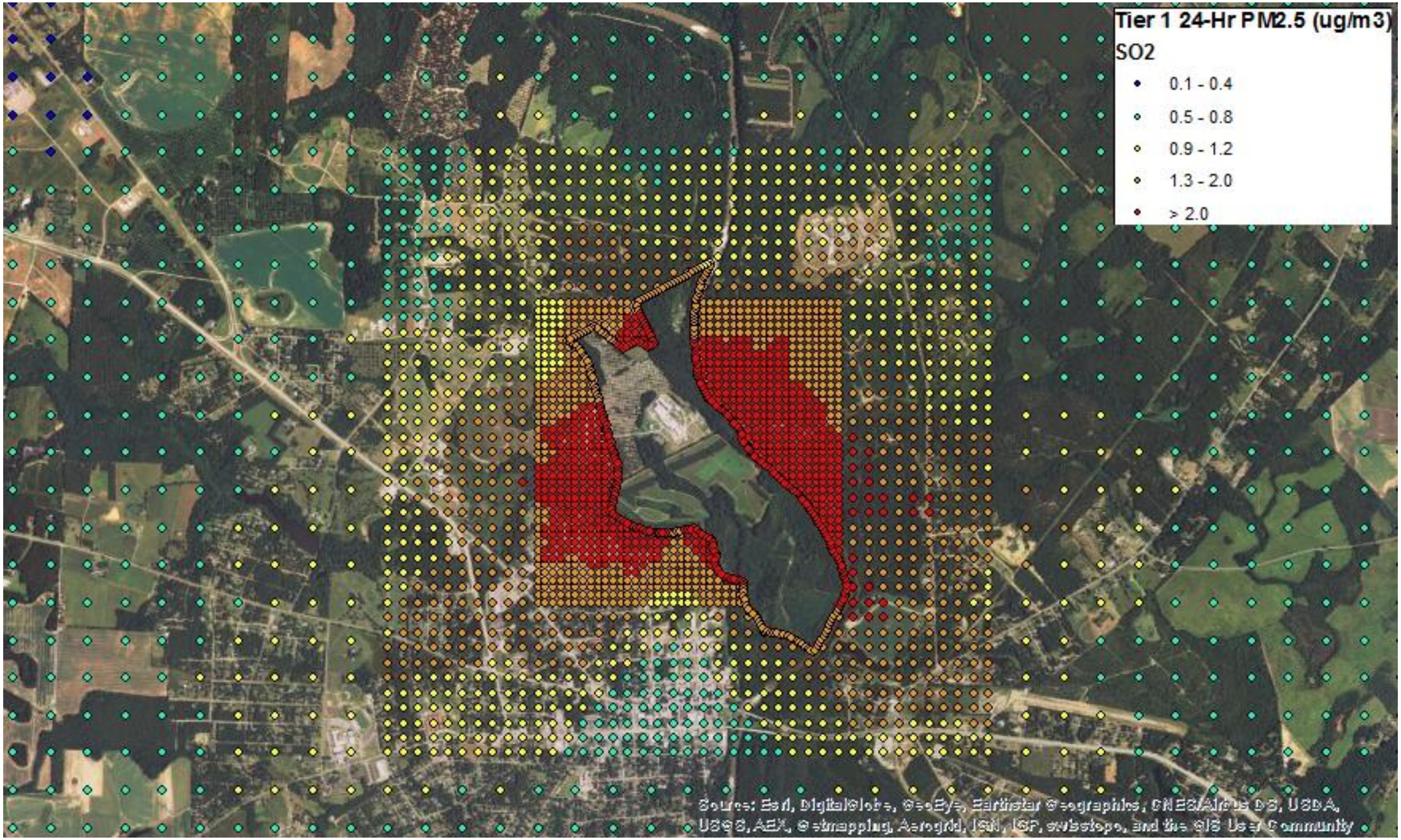
DAILY $PM_{2.5}$ – TIER 1 (EXAMPLE #2)



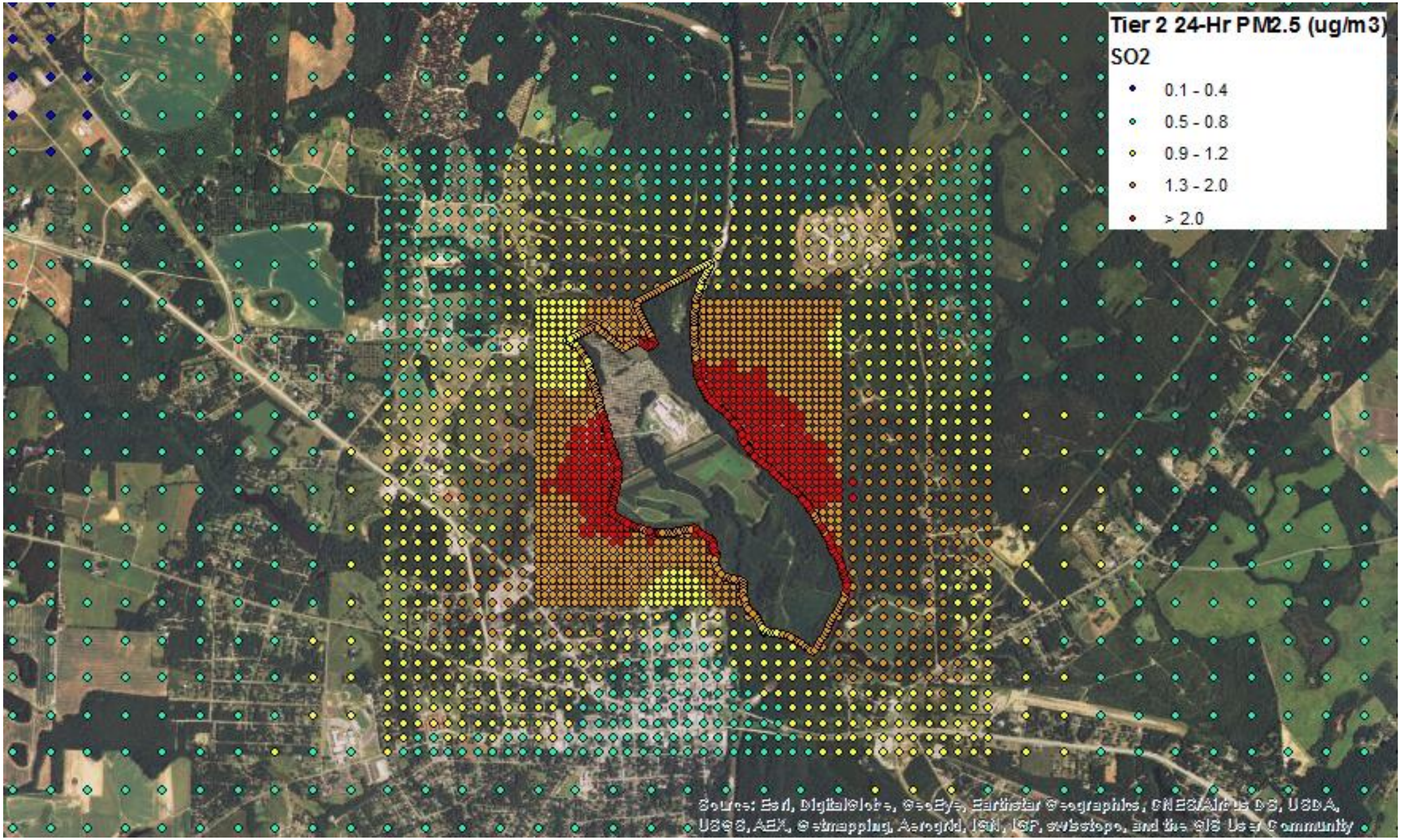
DAILY $PM_{2.5}$ – TIER 2 (EXAMPLE #2)



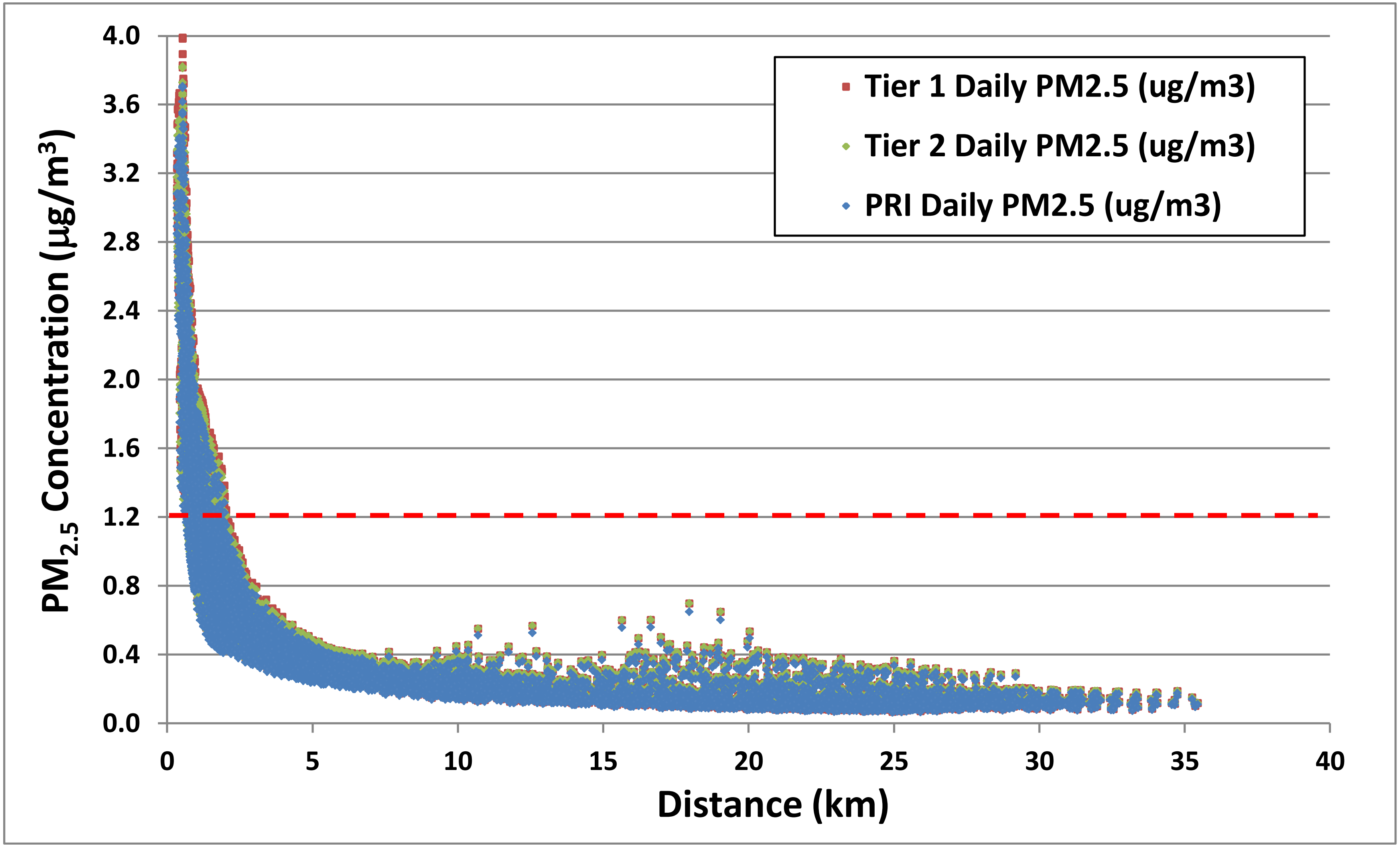
DAILY $PM_{2.5}$ – TIER 1 (EXAMPLE #3)



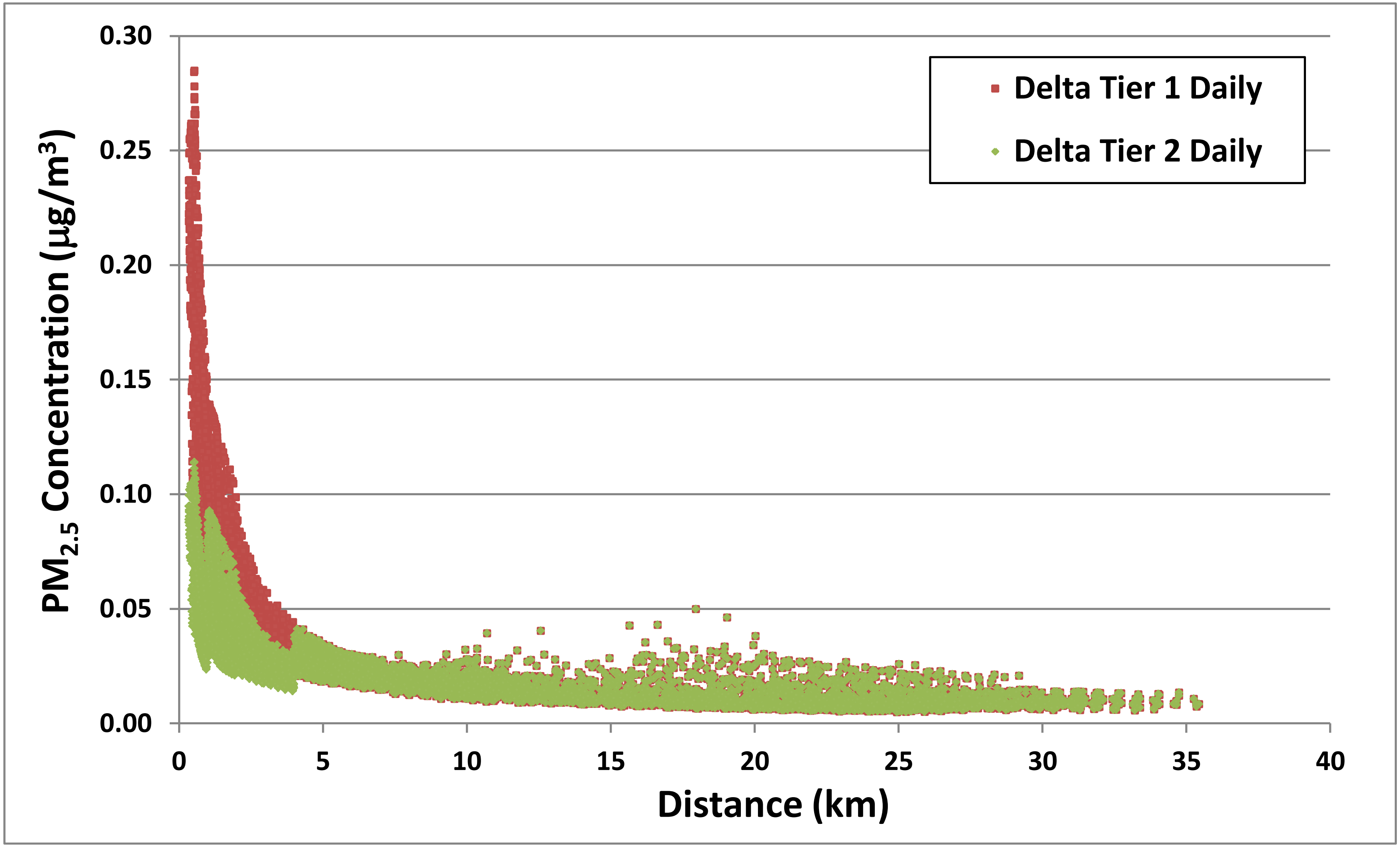
DAILY $PM_{2.5}$ – TIER 2 (EXAMPLE #3)



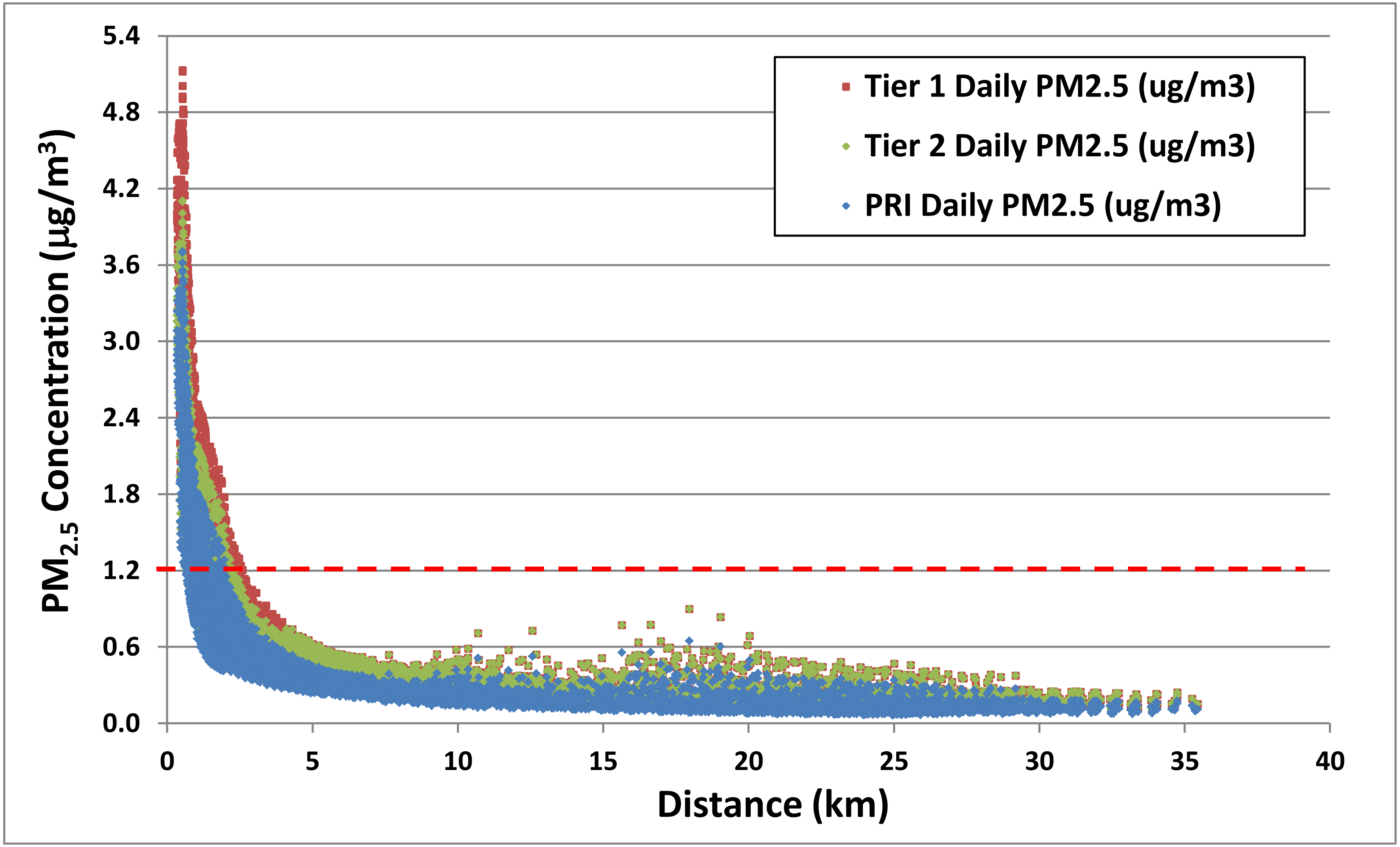
EXAMPLE #2 – DAILY $PM_{2.5}$ VS. SIL



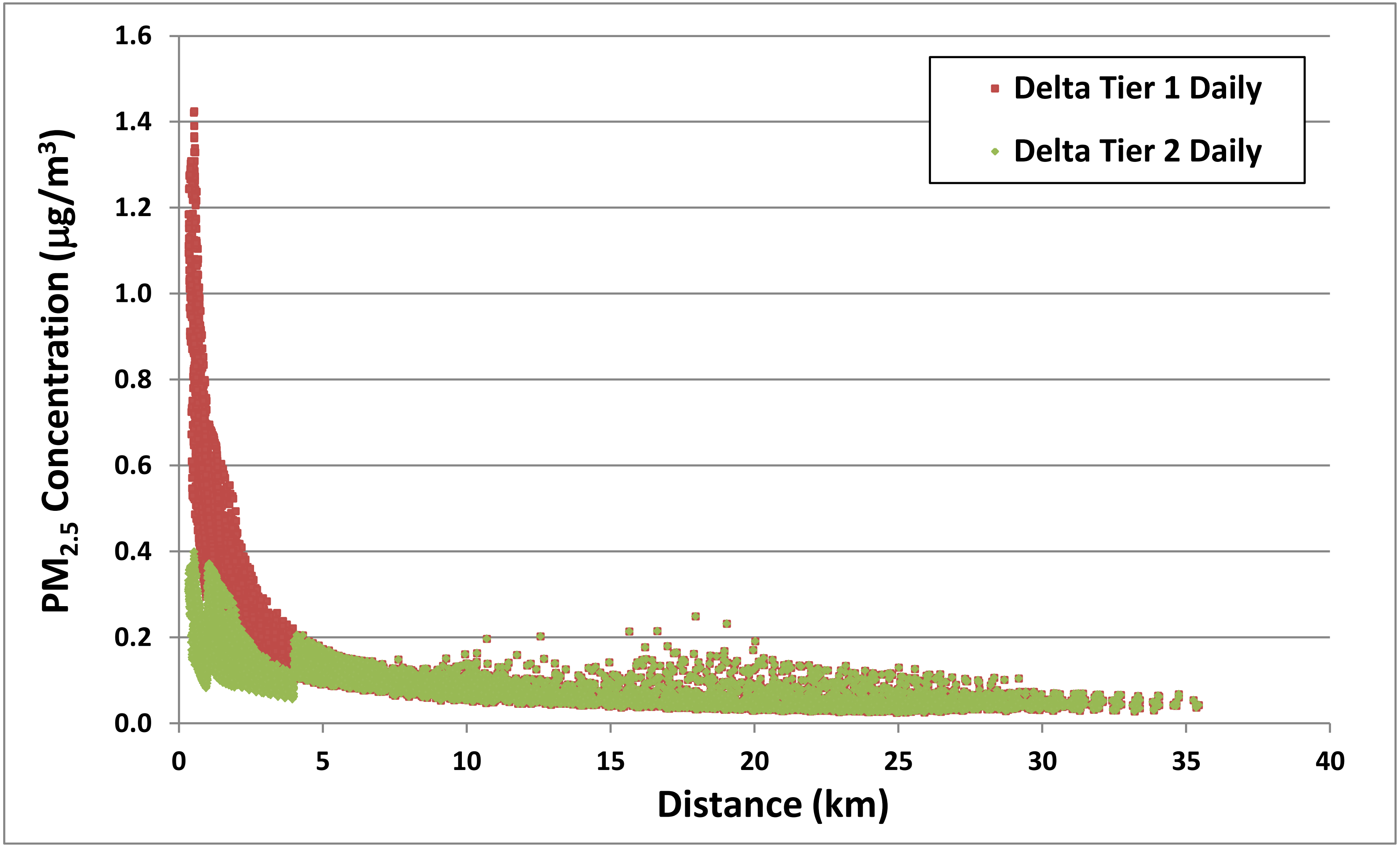
EXAMPLE #2 – DAILY SECONDARY $PM_{2.5}$



EXAMPLE #3 – DAILY $PM_{2.5}$ VS. SIL



EXAMPLE #3 – DAILY SECONDARY $PM_{2.5}$



EXAMPLE #4

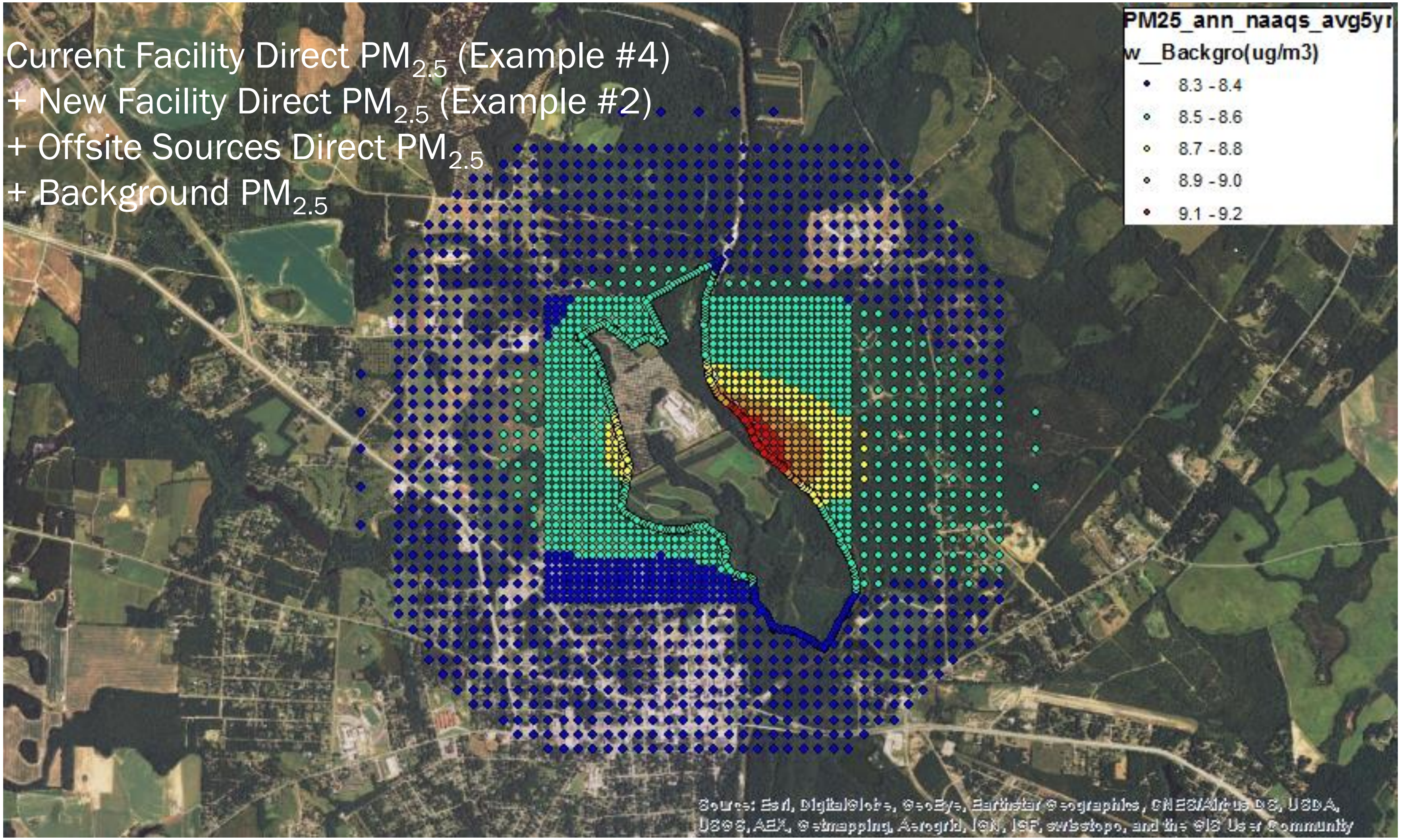
- Direct $PM_{2.5}$ emissions = 2.6 TYP
- SO_2 emissions = 0.2 TPY
- NOx emissions = 45.8 TPY

- $PM_{2.5}$ Scaling Factor =

$$\frac{\text{(SO2 TPY/SO2 Ratio) + (NOx TPY/NOx Ratio) + PM2.5 TPY}}{\text{PM2.5 TPY}}$$

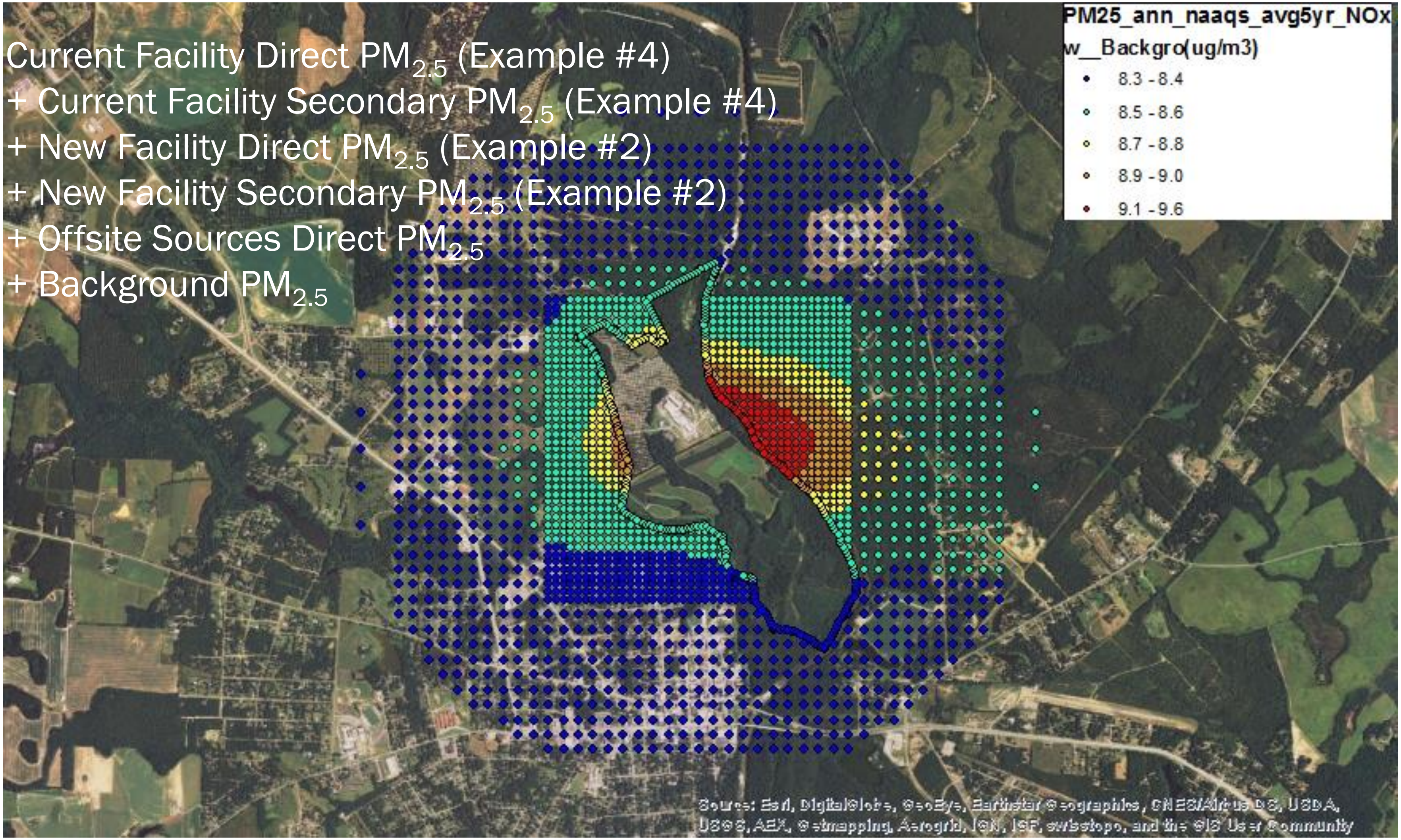
Distance	SO_2 Ratio	NOx Ratio	Scaling Factor	
< 1 km	~~20~~	50	1.352	
1 - 4 km	~~1~~	30	1.587	(Tier 2)
> 4 km	~~5~~	20	1.881	(Tier 1)

ANNUAL $PM_{2.5}$ – NO SECONDARY IMPACTS

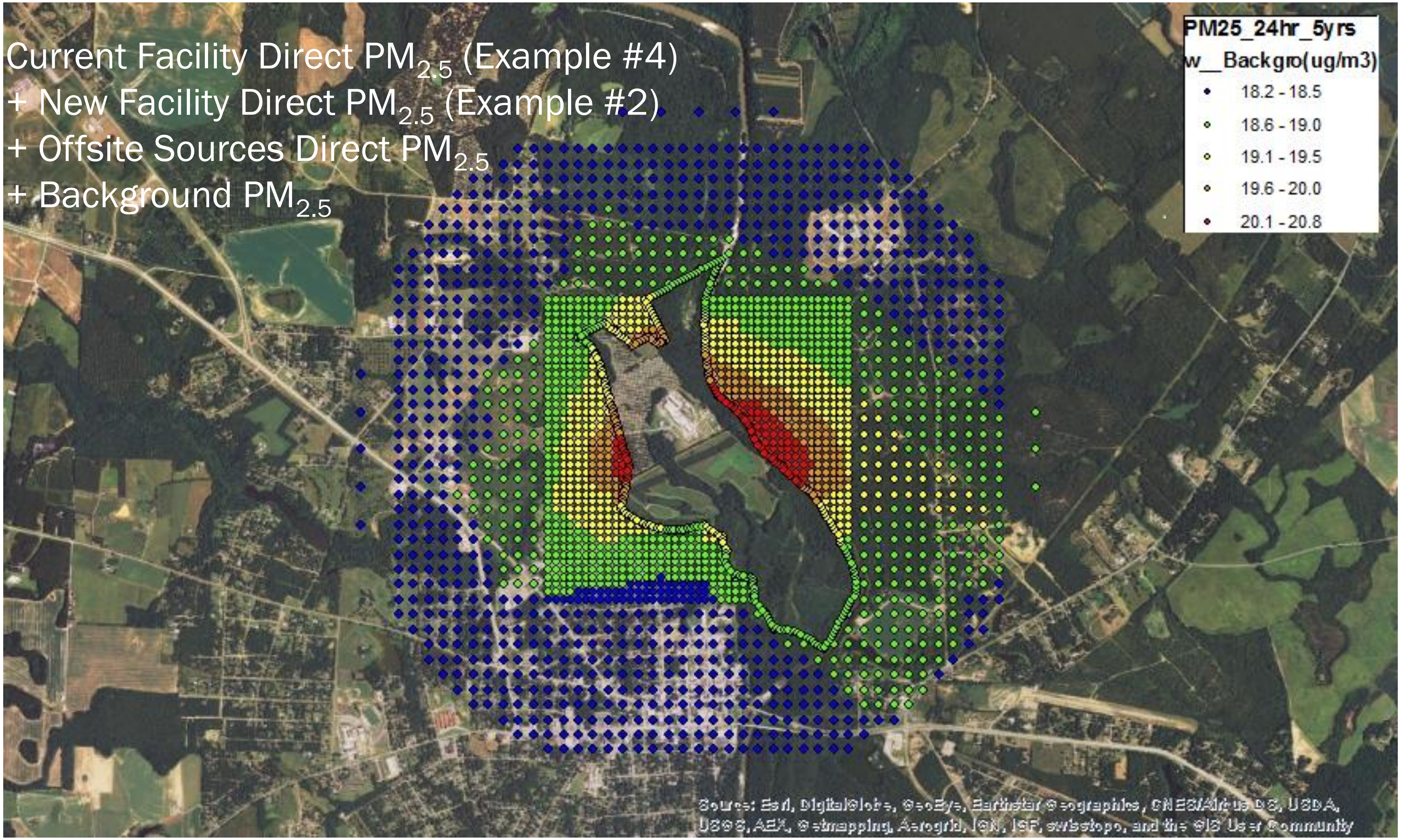


ANNUAL $PM_{2.5}$ – TIER 1

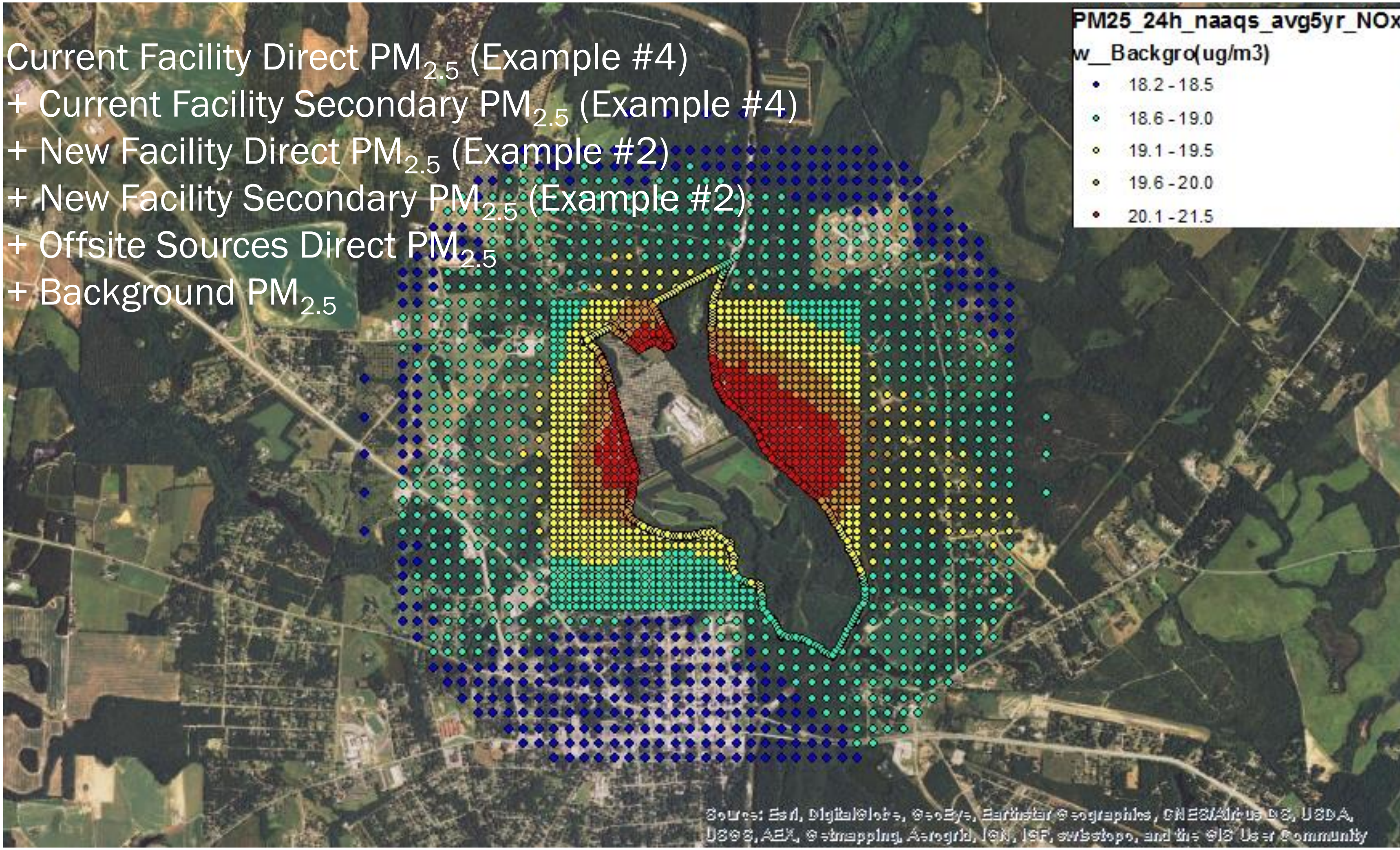
Current Facility Direct $PM_{2.5}$ (Example #4)
+ Current Facility Secondary $PM_{2.5}$ (Example #4)
+ New Facility Direct $PM_{2.5}$ (Example #2)
+ New Facility Secondary $PM_{2.5}$ (Example #2)
+ Offsite Sources Direct $PM_{2.5}$
+ Background $PM_{2.5}$



DAILY $PM_{2.5}$ – NO SECONDARY IMPACTS



DAILY $PM_{2.5}$ – TIER 1



TIER 3 OFFSET RATIOS

SO_2

Distance	Winter	Spring	Summer	Fall
< 1 km	250:1	70:1	20:1	40:1
1 – 4 km	130:1	35:1	10:1	25:1
> 4 km	40:1	10:1	5:1	10:1

NOx

Distance	Winter	Spring	Summer	Fall
< 1 km	175:1	80:1	50:1	70:1
1 – 4 km	100:1	45:1	30:1	45:1
> 4 km	40:1	20:1	20:1	20:1

TIER 3 MODELING

- Need to perform three model runs with three different sets of receptors
  - < 1 km, 1-4 km, and > 4 km
- Calculate seasonal $PM_{2.5}$ scaling factor appropriate for each distance bin
- Vary modeled $PM_{2.5}$ emissions by applying seasonal $PM_{2.5}$ scaling factors
- Combine the three model runs into a single file to calculate the design value concentration

EXAMPLE MERPs APPROACH

- Evaluated the maximum impact on ozone and $PM_{2.5}$ from each precursor
  - The maximum impacts will vary with stack height

$$MERP = (Precursor\ Emissions) * \frac{SIL\ Conc.}{Max.Model\ Conc.}$$

- EPA's recommended SILs for NAAQS
  - Ozone SIL = 1.0 ppb
  - Annual $PM_{2.5}$ SIL = 0.2 $\mu g/m^3$
  - Daily $PM_{2.5}$ SIL = 1.2 $\mu g/m^3$
- $PM_{2.5}$ SIL assumptions
  - Assume half $PM_{2.5}$ is primary and half secondary
  - Assume half secondary is due to SO_2 and other half due to NOx
  - Annual SO_2 SIL = Annual NOx SIL = 0.05 $\mu g/m^3$
  - Daily SO_2 SIL = Daily NOx SIL = 0.3 $\mu g/m^3$

EXAMPLE MERPs CALCULATION

Pollutant	Precursor	Modeled Emissions (TPY)	Maximum Impact (ppb)	SIL (ppb)	Example MERP (TPY)
Ozone	NOx	1,817.73	0.564	1.0	3,223

Pollutant	Precursor	Modeled Emissions (TPY)	Maximum Impact (µg/m^3)	SIL (µg/m^3)	Example MERP (TPY)
Annual $PM_{2.5}$	SO_2	4,200.35	0.0471	0.05	4,459
Annual $PM_{2.5}$	NOx	1,817.73	0.0104	0.05	8,739

These example MERPs are likely too high due to the use of a tall stack in the modeling. Various stack heights need to be tested before selecting the MERPs.

NEXT STEPS

- Document offset ratio approach and provide example calculations to permit applicants.
- Perform new offset ratio modeling with EPA's 2011/2017 platform and update analysis.
- Perform additional modeling to develop MERPs for SO_2 and NOx.

CONTACT INFORMATION

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